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Proceedings of International Conference on

Soybean Protein Foods

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Held at
Peoria, Illinois
October 17-19, 1966

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

FOREWORD

The sponsors of the International Conference on Soybean Protein Foods express their appreciation to those who were on the program and the many others who contributed time and effort in organizing the Conference.

These proceedings contain papers presented and the pertinent discussions on them.

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This report was prepared at the Northern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, 1815 N. University Street, Peoria, Ill. 61604. Copies are available on request.

CONFERENCE OBJECTIVES

Review potentials for soybean production and use as related to protein needs of the world.

Summarize nutritional and chemical studies made on soy protein products.

Discuss current status of commercially manufactured soy products.

Review marketing and distribution patterns of soybean protein products in various countries.

CONFERENCE SPONSORS

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PROCEEDINGS OF INTERNATIONAL CONFERENCE
ON SOYBEAN PROTEIN FOODS

Held at
Peoria, Illinois
October 17-19, 1966

INTRODUCTORY REMARKS

R. J. Dimler
Director, Northern Utilization Research and Development Division

On behalf of each of the sponsoring organizations, I take pleasure in welcoming you to this International Conference on Soybean Protein Foods.

About 5 years ago, we held a Conference at the Northern Division on Soybean Products for Protein in Human Foods. A number of you attended that Conference in which we discussed the contributions soybeans could make as a source of high quality protein, particularly in the developing countries. Since then, considerable progress has been made, not only in research on soybean protein foods but also in evaluating the needs of people throughout the world. The sponsoring organizations felt, therefore, that another Conference would be timely and helpful.

The program committee has brought together a full program and one which, I trust, you will find both interesting and informative. Emphasis has been placed on broad, yet thorough, coverage of protein needs and the relationship of soybeans to the meeting of these needs. At times, there may seem to be repetition, but I am sure that you will find that when similar subjects are covered, you will get the benefits of either different viewpoints or agreement which reinforce the conclusions which we may draw.

The importance of our subject certainly is indicated in part by the large attendance at this Conference. Your interest undoubtedly was stimulated by the announcements of speakers and their subject matter. The sponsoring organizations and I, thank the many who have given time and effort to the development of this program. We especially thank the speakers who will be sharing their thoughts with us.

I would like now to turn the meeting over to Dr. Nevin S. Scrimshaw, Head of the Department of Nutrition, Food Science and Technology, Massachusetts Institute of Technology. He is Chairman of Session I on Potentials for Soybean Production and Use as Related to World Protein Needs.

SESSION I: POTENTIALS FOR SOYBEAN PRODUCTION AND USE AS RELATED TO WORLD PROTEIN NEEDS

Nevin S. Scrimshaw, Presiding
Head, Department of Nutrition, Food Science and Technology
Massachusetts Institute of Technology

SOYBEAN PRODUCTION IN THE WORLD--LIMITATIONS AND POTENTIALS

Orville G. Bentley
Dean, College of Agriculture, University of Illinois

Around the world agriculture feels a sense of urgency springing from the stark reality that the demand for food exceeds the supply. The problem is an old one, but it wears a new and awesome face. The tabulation of the world's food budget in terms of calories, proteins, fats, minerals, and specifically food nutrients is an exercise unto itself. But a single poignant statistic will suffice to pinpoint the enormity of the problem--that an estimated two-thirds of the world's population is now living on nutritionally inadequate diets. In fact, the statistical documentation of this dilemma leads one to the conclusion that the clarion call is for a vigorous and imaginative program for meeting the problem on scientific, economic, and social fronts.

Hungry children want food! They need calories to meet energy demands of their bodies and protein for growth and proper development. These and other essential nutrients are woefully lacking, but it is generally agreed by students of world food problems that the shortage of protein is the most critical need now and in the foreseeable future. It is appropriate, then, that the programs for the International Conference on Soybean Protein Foods be aimed at an examination of the basic problem and that we probe in depth a promising avenue for at least a partial solution of the problem through the expanded use of soybean proteins.

Our purpose should not be to analyze the relative efficiency of plant versus animal systems for producing the proteins, nor to evaluate various plants and oil seeds as sources of the quality protein needed by man himself or his animals, or for industrial uses. The purpose of this Conference is to discuss a promising and proven source of plant protein and edible oil--the soybean. This crop has earned a place in the worldwide scheme of food production because of its agronomic adaptability and high per hectare productivity of quality products--namely, protein and edible fat. A scientific symposium on soybean protein foods must of necessity be specific and technical, but it is equally appropriate that background papers be included as a means of placing the technical questions in a more meaningful perspective. The intent of this presentation is to review the worldwide

production of soybeans and, using this base line, comment on potential for expanded production and some of the limitations inherent thereto. The subject is a broad one and stringent topic selection was a necessity. To get an overall view of worldwide production by geographic areas, we have selected North America (primarily the United States), the Soviet Union, Eastern Europe, Eastern Asia, and Latin America.

But before we begin a discussion of production figures, a few historical comments about the soybean seem apropos.

In the early part of this century, C. V. Piper, (a noted U.S. Department of Agriculture plant scientist) recognized this potential when he stated, "These beans are gold from the soil. One must truly stand in awe of their potential power in the life of the western world" (1).

Philip S. Chen (2) summed up their nutritional value, "The soybean, though rarely recognized as a dietary constituent, is a food that is as nearly perfect as cow's milk, but at the same time is rich in iron and vitamin C (when sprouted), and its milk can be used as a substitute for cow's milk for individuals who are allergic to it.

"The yield of protein from soybeans, weight for weight, is approximately twice that of meat; four times that of eggs, wheat, and other cereals; five or six times that of bread; twice that of lima and navy beans, walnuts, filberts, and most other nuts; and twelve times that of milk."

Mildred Lager (3) saw its values this way: "The history of the soybean is a fascinating story of a little round bean that has literally been a golden nugget to the oriental world. Soybeans are perhaps the world's oldest food crop and for centuries nutritionally they have meant meat, milk, cheese, bread, and oil to the people of Asia. Soybeans can rightfully claim the honor of being one of the most concentrated and nutritive foods known to man.

"Because of their great food value, they not only have long had a definite place in the oriental diet but now belong in the diet of America and of the entire world. They are nutritional nuggets that we must learn how to use because they will be an important factor in the balanced diet of the future."

The expansion of soybean production has been primarily in the United States. When we compare 1965 production with the 1950-54 average, the total world production outside the United States has actually declined. The Foreign Agricultural Service in the U.S. Department of Agriculture estimates that the 1965 world production totaled 32,314,000 metric tons (1,184,870,000 bushels). What is the potential production in the future? This is a matter of conjecture and no one is willing or capable of predicting the possible size of the future soybean crop. We can, however, examine the likely factors that are enhancing and limiting current production and that will affect future output.

An Overview of Worldwide Soybean Production

Although the earliest recorded origins of soybeans date back to 2800 B.C. in China, North America (primarily the United States), leads the world in soybean production.

Soybean production as a real commercial crop in the United States began in the 1930's. Acreage, yields, and production have moved upward almost continuously since that time (Fig. 1). In 1965, our American farmers produced about 71 percent of the world's output (Fig. 2).

The establishment of the soybean in this country did not come without bold pioneering and men of vision. William J. Morse of the U.S. Department of Agriculture walked the fields of China and Manchuria to bring back 5,000 seed selections. Right here in Illinois, men like Burlison, Woodworth, and Hackleman at the University of Illinois, and Bradley and Staley who began processing the crop, played a key role, along with others, in establishing soybeans in the Corn Belt.

In this country, about 77 percent of the soybean acreage is found in the North Central region. The lower Mississippi Valley and the Southeastern coastal plain have also become important producing areas, (compare Figs 3 and 4).

Over the years, soybeans will yield the second highest net income from any field crop raised in the Corn Belt. Only in years of excellent soft red winter wheat crops will wheat exceed the value of soybeans.

When farmers discontinued raising their own horsepower, hay and pasture and oat prices weakened as demand slackened. Grain farmers turned to soybeans as a new crop that replaced the lower value oat and forage crops. However, during the past 15 years, a relatively stable and favorable relationship between soybean-prices-and-yields to corn-prices-and-yields has encouraged farmers to expand their soybean acreage.

In the South, soybean acreage has surpassed other crops in several states. And although cotton is still the major money crop, acreage restrictions on cotton have opened the way to soybeans. The southern states account for about 20 percent of U. S. soybean production.

A major factor for the acceptance of soybeans in the cotton-growing South is the research program that has helped to develop high-yielding, disease-resistant, and nonshattering varieties. Experiments on cultural practices and machinery adapted to easy harvesting have also contributed to its development.

Soybeans fit well into the cotton field rotation. They also work well with cotton production timing and use of cotton machinery. In Arkansas, the traditional rice and cotton state, soybeans occupy over 50 percent of the cultivated land.

Along the lower Atlantic coastal plain, South Carolina, Georgia, Virginia, and North Carolina planted about 7 percent of the total U.S. acreage in 1965. With no acreage restrictions on soybeans and most of the traditional crops in this area under control, soybeans presented the best choice of crop acreage expansion. Increasing labor costs for other crops have encouraged farmers to look for crops with good profit potential, relatively low production cost, and low labor requirements. Soybeans fit well in all three categories.

In 1925, U.S. farmers harvested a modest crop of 4.8 million bushels, or 130,907 metric tons. Yields averaged about 11 bushels an acre, or 741 kilograms per hectare (kg./ha.). Last year U.S. soybean growers set another new production record with 843 million bushels (22,990,000 metric tons) with prospects for over 925 million bushels in 1966 (25,227,000 metric tons). Yields in 1966 are expected to average 25.1 bushels an acre (1691 kg./ha.)

Such progress did not come by accident but shows that technology can contribute to a valuable crop. At the same time a supporting industry has continually expanded to provide a market for the crop and has handled the vast crushing operation.

From the 1965 crop of 843 million bushels, industry crushed 538 million bushels. Exports totaled 251 million bushels, while seed, feed, and residual uses took 50 million bushels. And 35.7 million bushels of stocks remained on August 31, 1966.

In addition to bean exports, oil exports ran about 454,500 metric tons--about one-fourth of total production. Meal exports totaled about 2.2 million metric tons--about one-sixth of total meal output.

Production and development of soybeans in the U.S. have centered upon the use of the crop to fill the most important needs during the time of soybean expansion--meal for livestock feeds and oils, primarily for food products. While direct uses of beans for food have been insignificant, the know-how is available should the need enlarge in the future.

From the early 1920's, the Corn Belt States have been the main producing areas because of the favorable climatic and soil conditions and also because of the adaptability of corn farming practices to soybean cultivation.

Through efforts of research workers, important improvements have been made in climatic adaptability, yield of seed, oil content, and resistance to lodging, shattering, and disease. Although soybeans are adaptable to a wide range of climatic and soil conditions, soybean cultivation would be confined to more limited areas than it is today without the effort of plant breeders to develop varieties better suited to local conditions in the United States.

The three main reasons for the increase in soybean yields have been (1) improvement of varieties, (2) technological improvement in harvesting soybeans, and (3) improved planting and cultural practices including better weed control and increased fertilization.

Various government farm programs for both soybeans and other crops have been an important factor in development of soybean production. As early as the 1930's, programs of the Agricultural Adjustment Administration contributed directly and indirectly to expansion of soybean acreage. During the war years, price support programs encouraged production. After the war, restrictions for cotton, corn, and wheat resulted in decreased acreage of restricted crops and increased soybean acreage because the released land was diverted to soybeans. The Public Law 480 programs, under which soybean and cottonseed oils have been exported since 1954, have also had an indirect but effective influence on soybean acreage expansion through disposal of surplus oil.

The intensive cooperative soybean breeding program in the United States began with the establishment of the U.S. Regional Soybean Laboratory in 1936. Under the leadership of J. L. Cartter, 39 improved commercial varieties have been released from the program, in cooperation with the Agricultural Experiment Station. Today, they are planted on 90 percent of the acreage. Improved disease-resistant versions of some of these varieties produced through backcrossing were released in 1963. New varieties with a higher oil content made the beans more valuable for processing. While 16 percent oil was common 30 years ago, 20 percent oil is normal today. Science and industry have worked together to produce productive varieties, processing facilities, and production know-how that has made Illinois the No. 1 soybean state and the United States the world leader in soybean production.

Intensive research at the State Experiment Stations in soybean-growing states has contributed further important knowledge to advance production techniques and methods. Planting date studies, planting methods and row widths, double cropping, and weed control have all provided important additions to the success formula and profitable soybean culture.

Extensive field trials on nitrogen application have shown no appreciable benefit from nitrogen fertilizer on well-nodulated soybeans. Studies have established the importance of nodulation for getting maximum yields.

There seems to be general agreement that a soil pH of 6.0 to 6.5 is most desirable for soybeans. On soils of lower pH, limestone applications produce favorable yield response.

The rapid expansion in soybean culture points out new problems for which answers are yet to be found. Soybeans respond favorably on fertile soils but more knowledge is needed about specific fertilizer applications. The possibility of raising the nitrogen supply by the development of a specific Rhizobium strain to inoculate each soybean variety should be further explored. More specific weed control chemicals would reduce production cost and weed competition losses.

While soybeans for direct human consumption have been the incentive for increased production in the Far East, the more rapid growth in the Western

World has been for meal to feed livestock. And the expanding livestock industry is providing more and higher quality protein foods in Europe and the United States.

At the same time, the oil--refined, deodorized, and purified through highly improved processing techniques--has provided a basic ingredient for margarine, shortening, and salad dressings to meet the increasing demands of an expanding population when other vegetable oils could not meet the needs.

The growth in soybean meal and soybeans-for-crushing exports to western countries, particularly to Europe, has been phenomenal during the past few years. For example, the European Common Market countries bought about 1,409,000 metric tons of soybean meal and meal equivalent in the 1959-60 marketing year; in 1965-66 they will buy about 3,388,000 metric tons--more than twice the amount of 6 years ago (Fig. 5).

Purchases by Britain and Scandinavia advanced from 333,000 to 644,000 metric tons. Other European countries boosted their buying from 96,000 to 706,000 metric tons.

Production in Eastern Asia

Soybeans originated in China and for many centuries their culture was confined to the Asian countries. However, after World War I their production spread rapidly into the Western World and has since surpassed the original homelands.

Production figures for Mainland China are estimated and vary considerably from different sources. Efforts are apparently underway to promote increased soybean production by raising per-unit yields, and farmers are being urged to grow more soybeans. Latest Foreign Agricultural Service estimates for 1965 (Fig. 6) show a production of 250 million bushels (6,818,000 metric tons) compared with the 1950-54 average of 330 million bushels (8,999,000 metric tons). The most recent estimate gives China about 21 percent of the world output. Other countries in Asia--mainly Korea, Indonesia, and Japan, and U.S.S.R.--produce about 4 percent of the world's production.

The wide range of climatic and soil conditions in China permit practically every known crop to be grown to some extent. The soybean is grown almost everywhere in China, but about 60 percent of the acreage, excluding the Manchurian plains, is confined to the three northern provinces of Shantung, Kiangsu, and Honan.

The average planted acreage is declining. The average acreage was 28,218,000 acres (11,424,000 hectares) from 1950 to 1954 compared to 20,015,000 acres (8,103,000 ha.) in 1965. Average yields have increased slightly from 11.7 bushels per acre (788 kg./ha.) in 1950-54 to 12.6 bushels (849 kg./ha.) in 1965.

Most of China's production is consumed as food, less is processed for oil and little is exported (Fig. 7). The main foods are soybean sprouts, soybean milk, and soybean curd.

Indonesia produced an estimated 373 million metric tons in 1964, more than 1 percent of the world output, and ranks third behind the United States and China. This production is primarily for domestic use and little is known about the potential for further expansion.

Soybeans grow throughout Japan. Here the crop is a staple food used in soy curd (tofu), soy paste (miso), and soy sauce (shoyu). The crop is considered a food grain, like rice and wheat, and serves as an important source of protein in the Japanese diet. Some of the soybean food items, such as shoyu (soy sauce), tofu (soybean curd), and miso (soybean paste), are now familiar to some American people. In addition, such soybean foods as natto (fermented soybeans), kinako (roasted soybean flour), and aburage (fried tofu) are popular items among the Japanese.

During the 1930's, Japan consumed about 1 million tons, or 36.7 million bushels, of soybeans each year, of which 30 to 35 percent was of domestic production; the remainder was imported from Manchuria. Of the 1 million tons, 40 percent was crushed into oil and meal and the remainder was used in soy foods.

Domestic production increased after World War II and reached one-half of a million tons in 1952, but has not increased since that time, perhaps due to the availability of U.S. soybeans. In 1965, total consumption amounted to 2 million tons and is expected to increase further in the future.

As consumption has increased in recent years, the ratio of consumption going into the crushing industry has increased more than use in food industry. Use of soybean meal in feed manufacturing is becoming more important as the livestock industry grows.

Domestic production has declined since 1950 with 1965 output only about one-half of the 1950-54 average. United States imports have risen steadily.

The government has also tried to induce production through certain policies. Production has declined despite various measures of protection such as the 10 percent import duty since October 1956; the high support prices of $140 per metric ton ($3.80 per bushel); and important restrictions by the foreign exchange allocation system.

In Taiwan, soybean acreage has risen to meet the increased demands of population and expanding hog production. Introduction of new varieties paved the way for increased acreage and production. These new varieties

were of the yellow seed type--good for food and oil and beancakes. They yielded significantly higher than the native green or black beans and fit better into the local cropping and rotation system.

Plantings have climbed from 7,400 hectares in 1948 to 54,000 in 1964. Production moved up from 576,000 bushels (15,700 metric tons) in 1950-54 to 2,117,000 bushels (58,000 metric tons) in 1964. Yields rose from 9.2 bushels (620 kg./ha.) in 1950-54 to 16.8 bushels per acre (1132 kg./ha.) in 1964.

Introduction of new varieties has paved the way for increased acreage and production. The new Sankuo variety produced average yields of about 1,500 kilograms per hectare, more than double the yield of native green or black beans grown in the southern areas. In the mild Pacific climate where three crops a year are possible, soybeans fit into the summer crop between July and November, preceded by rice, and followed by wheat, rape, broad beans, or other vegetables in winter.

Another new variety, Palmetto, released in 1957 for southern Taiwan, is an American variety of yellow seed type and originally obtained from Nanking, China. It fits in the gap between the second rice crop and the transplanting of the first rice crop in the following year.

The Shih-Shih is a Japanese variety introduced in 1954. Owing to its short time to maturity (from 82 to 88 days), it fits into a very intensive cultivation system making four crops a year possible.

Improved cultural practices such as line sowing, proper drainage, and interculture have gone hand-in-hand with improved varieties to boost yields. Better storage facilities have boosted seed germination. Intercropping with sweet potato has demonstrated how net profit per hectare can be increased by 1,500 to 2,350 Taiwan dollars per hectare.

In Thailand, government policy has been designed to encourage crop diversification, extend transport facilities to the more remote regions, and expand the area under irrigation. This country has now emerged as a leading exporter of foodstuffs in Asia. It has surpassed Rumania and Yugoslavia in corn exports besides being a principal rice exporter.

In the dark clay soils of the northeastern region, the lands are intensively cultivated with much double-cropping of rice. Or rice may be grown with a combination of other crops such as soybeans and peanuts.

Soybeans must compete with other crops in this productive agricultural country. Between 1950 and 1963 acreage rose and production expanded. However, production has fallen off from a 1963 high of 1,213,000 bushels to 705,000 bushels in 1965 (33,000 metric tons to 19,200 metric tons).

In India, soybeans have failed to create large-scale interest as a good food or forage crop. The reasons are varied. They range from a lack of sustained experimentation on the agronomic and economic suitability of the soybean in the local cropping pattern to the availability of proper marketing channels.

However, research work shows great promise for this land where food needs are so urgent. Soybeans have been tested at various locations for many years.

In the central state of Madhya Pradesh, trials on a government farm in 1963-64 showed that short duration crops--like soybeans grown in the rainy season before the wheat crop--make it possible to earn more profit per acre than when only wheat is grown. Similar tests at the Uttar Pradesh Agricultural University in the foothills of the Himalayas also suggest that American varieties can be adapted to India. In some experiments it was evident that soybean yields increased in subsequent years as compared to the first year, showing that nitrogen-fixing bacterial population may not be there in the first year. Bacterial culture for efficient nitrogen fixation may further show increased yields in these trials.

In the Soviet Union, 1965 production was 16 million bushels (436,000 metric tons). This was equal to about 1.3 percent of the world output. Production in the 1960's has more than doubled the annual average production of the 1950's.

In southern European Russia, commercial soybean plantings were recorded in the 1870's. In the Far East, soybean cultivation may be even older as part of the agriculture of the local Chinese. Before the Revolution, acreage was small, however.

Under the Soviet regime, great efforts have been made to develop soybean cultivation. Considerable resources have gone into research and development, and there is an impressive body of literature in Russian.

The soybean is consistently described as an industrial crop with no indication that the crop is intended for direct human consumption as beans. The usefulness of the crop is always reported in terms of oil and industrial raw materials drawn from the protein, such as synthetic fibers and other plastics. Use of the press cakes as stock feed is also reported. Soybeans are also grown for feed directly as hay, green feed, and silage.

Since 1950, total acreage has expanded in the Far East. Plantings in Europe have dwindled to only a few hectares a year. The decline in Europe runs parallel to soybean decline in Rumania and Bulgaria. Most of the Russian soybean production now centers in the Far East, with 300 to 400,000 metric tons a year on 800,000 hectares. Yields averaged 470 kilograms per hectare from 1962-64. Soybean expansion in the Far East came as part of the virgin lands program. Soybeans expanded more and now outrank wheat in cropland hectares in this area.

Although soybean yields are low, so are all crop yields in the Soviet Far East. The wheat yield is only 670 kilograms per hectare, so the yield ratio is favorable to soybeans if agriculture is at all profitable.

Cost accounts from farms in the Soviet Far East indicate that soybean-growing farms are likely to break even at a soybean yield of 500 kilograms per hectare, not much more than the recorded average. The price used in these calculations is close to $7 a bushel. Experiments have produced more than three times the average yield, and higher yields could become general.

Latin America is a relative newcomer in soybean production. Brazil is the only country where large acreage has been planted for more than a decade. In recent years soybeans have been planted in Argentina, Colombia, Mexico, Paraguay, and Surinam. Brazil is the major exporter with smaller amounts coming from Paraguay and Surinam. Venezuela is a major importer and Mexico imports some.

Estimates for 1965 show that Brazil produced 16,610,000 bushels (453,000 metric tons), Mexico produced 2,482,000 bushels (67,690 metric tons), Colombia produced 1,835,000 bushels (50,000 metric tons), Paraguay 660,000 bushels (18,000 metric tons) and Argentina 360,000 bushels (9,800 metric tons). Total production of Central and South America would be only slightly more than 1 percent of the world output.

In Brazil, about 90 percent of the production is concentrated in the state of Rio Grande do Sul, the southern-most part of the country. The balance is grown in nearby Santa Catarina and Parana. The climate is similar to some of our southern states, such as Louisiana and Mississippi. Although the soybean appears to have been accepted as a food crop, its more important uses are for oil and concentrate feed. A major processing plant has been built near Porto Alegre.

Soybean plantings have been over 300,000 hectares, more than one-tenth of the cropland in the State. Yields of normal years have averaged 10 quintals (1 metric ton) per hectare or about 15 bushels per acre. By comparison wheat yielded less than 10 quintals and corn 14 quintals.

Prices in the late 1950's exceeded corn sufficiently so that soybeans may have been competitive. Wheat enjoys a price advantage because of national policy favoring this crop.

In Mexico, production began very recently. Almost all acreage is in the State of Sonora, bordering Arizona and Southern California. Here plantings started in 1959. Highest yields to date were obtained from Hood, Hill, and Lee varieties, material drawn principally from the U.S. Department of Agriculture and some State Agricultural Experiment Stations. In the Yaqui Valley, soybeans are always grown under irrigation where they fill in successfully as a second crop following wheat and cotton. Yields of 20 quintals per hectare are slightly higher than the U.S. average--thanks to irrigation.

In Colombia, soybeans are also a relatively new crop. Acreage is concentrated in the Cauca River Valley on the western slope of the Andes, a tropical river valley recently developed as a commercial farming area with modern agricultural methods. With two rainy seasons, and corn and cotton the main crops, soybeans fill in to take advantage of the second rainy season because they can be harvested about 90 days after planting. They must compete with other edible beans, so price relationships and market outlets will determine future output.

Argentina has not become a major soybean producer, ranking below Brazil, Colombia, and Paraguay in 1965. Soybeans have been grown on a trial scale for some time but still production is quite modest. Acreage up to a few years ago amounted to about 1000 hectares, most of which is grown in the State of Misiones, the far northeast area bordering upon Rio Grande do Sul in Brazil. The reason given for failure of the soybean to spread in Argentina is the low oil content, an overabundant supply of animal products, and acreages of sunflower, groundnuts, and linseed that produced more oil than soybeans. In recent years there has been expansion in the pampas.

In Australia, successful results with American varieties have greatly increased acreages and production, especially in the states of Queensland, New South Wales, and Victoria. Production figures on a worldwide basis, however, are not significant.

In Europe, although attempts to grow soybeans have extended over many years, it is only within the last two decades that there has been an appreciable rise in production. At present, production is confined largely to European Russia, Bulgaria, Yugoslavia, Rumania, and Czechoslovakia. Production of all countries outside Russia in 1964 totaled only 15,000 metric tons--a small part of the worldwide output.

Prospects for Further Production

A look at the worldwide figures of acreage, yields, and production over the past 15 years will point rather significantly to those areas where the potential exists for further expansion.

In the United States we have seen soybean acreage spread out from the Corn Belt--north and south, east and west. With the alternate choices between corn and soybeans over a large area of the Corn Belt, the price ratios will direct farmers in making their decisions in favor of that crop which will give them the most income. While there will be a specialization toward corn farming and soybean farming, many farmers will continue to grow some acreage of each crop.

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New soybean varieties are likely to boost average yields a bushel or two at a time. There are no immediate prospects of a breakthrough in yields as we saw hybrid corn affect the corn crop 30 years ago.

Hybrid soybeans are a plant breeder's dream but the obstacles still seem insurmountable. Lack of male sterility, difficulties in large-scale crossing, and high cost of seed planted per acre are the major problems.

As time goes by and herbicides for weed control in soybeans become more effective, we may expect to see more close planting which will result in higher bean yields and in greater competition for land use by soybeans.

If weed sprays for soybeans can be developed that are as effective as 2,4-D and pre-emergence materials in controlling corn weeds, then soybeans will compete even more with corn for Corn Belt acreage provided the cost is not too high.

Production has not extended very far west in the Central Great Plains, except where the crop can be irrigated. With irrigation, especially in the pod filling stage, soybean culture can be extended into this area successfully. The high plains of Texas and central Nebraska would be typical of such areas.

Some expansion to the West is possible under irrigated conditions. Research trials in Oregon, Washington, and California show yields as high as 80 bushels an acre. But where water is limited, the highest value crops will be favored.

The greatest expansion in this country in the immediate years ahead is likely to be in further acreage within the areas where soybeans are now grown. If cultural practices such as narrower rows, weed control, and use of adapted varieties are put into more widespread use, we could see some further yield improvement. If the market is ready to buy beans at attractive prices, American farmers have the capacity to produce at considerably more than the present high production levels.

<u>In southeastern Europe and Russia</u> soybean acreage has declined, but in the Far East it has been expanded. One Soviet writer credits this Far Eastern expansion to the summer rains in the Pacific coastal areas.

Western Europe has probably not developed as a soybean area because summer climate favors feed crop production instead of soybeans.

The leading oil crop in the U.S.S.R. and Eastern Europe is the sunflower, cultivated in large quantities all the way from the Danube basin to central Asia. Outside this area, sunflowers for oil seeds are grown only in Argentina to any large extent. Under eastern European conditions, sunflowers give higher yield than soybeans with a higher extraction rate, which makes a

decisive difference. In low income countries, the yield of fat is more essential than any added supply of stockfeed from meal or press cakes. Rapeseed also seems to find a place as an oilseed in Russia and parts of Canada.

In Thailand, soybeans can fit the agronomic requirements. The real question is whether it can compete for scarce land resources by producing sufficient yield and finding sufficient market compared to other crops which also grow well there.

Japan has continued to be a major consumer of soybeans but acreage and production have declined. Labor costs have risen; soils and climate are not favorable to widespread production as we know it here in the United States. Japan has recognized that the yield potential of soybeans is not as great as for other crops. Production is not likely to go up as long as imports are possible.

Projections of the Ministry of Agriculture suggest that soybean plantings will decline to only half the area planted in 1958-60 although yields will increase considerably. Cost of production is high in comparison to the United States.

Brazil shows good prospects for expanding soybean output. It has the land and the climate and is showing a steady uptrend. The 1965 output jumped 50 percent over 1964 and four times the 1950-54 average, primarily because of production expansion in Parana.

Colombia also shows a rising production trend with potential land available for expansion.

In Argentina, low oil content plus an abundant supply of animal production have not produced a need or desire to expand the soybean industry. Argentina grows substantial acreages of sunflower, groundnuts, and linseed, all of which have higher oil extraction rates than soybeans. However, Argentina corn competes on world markets. So there is reason to believe that soybeans as an export crop might be as profitable as in the United States.

In Mexico, soybeans have been raised as an irrigated crop with moderate water requirements. The successful experience of the Yaqui Valley is likely to be repeated in other irrigated areas in Mexico.

Summary

Soybeans are recognized worldwide as an efficient producer of high-quality protein and edible oil. The soybean plant has a high degree of adaptability and favorable agronomic characteristics which contribute to its acceptance as an economically sound crop.

The Foreign Agricultural Service of the U.S. Department of Agriculture estimated the world production of soybeans at 32,314,000 metric tons in 1965. The United States and Mainland China produced about 91 percent of the world supply of soybeans in 1965. Although soybeans can be grown over widely scattered areas of the world from a tropical climate to the northern and southern temperate zones, the decision to grow this crop is made by individual growers, who base their analysis on the economic incentives and whether a crop of soybeans will give a better return than could be expected from growing other adaptable crops on the same land.

The climatic conditions of western Europe, western United States, western South America, and other areas of similar climate will discourage acreage expansion because of unfavorable growing conditions.

In some countries, government policies may influence growers to plant other crops. But, if prices for various crops are permitted to direct production, soybeans will be planted when the growers expect more profit than from an alternate crop.

Soybeans have developed for reasons other than for direct human food. It is doubtful that soybeans can compete with other vegetable crops for direct human nutrition. The real potential seems to be for satisfying the food wants of prosperous people.

During the last 10 years, production in the United States has expanded while production in the rest of the world has declined. All factors considered, the major producers of soybeans in the next 10 years will most likely continue to be the United States and Mainland China. Of the 150 million bushel increase (4 million metric tons) in 1965 world production, 95 percent occurred in the United States.

Rising output in Brazil, the Soviet Far East, Canada, and Mexico will give these countries a rising share of the world output.

Soybeans rank far ahead of other crops as a protein source for both human and animal use. When the needs for protein are great enough and where the market system recognizes this need, there is much potential for growing more soybeans--the wonder crop of the 20th century, the gold from the soil, and the nuggets of nutrition for a hungry world.

Acknowledgment

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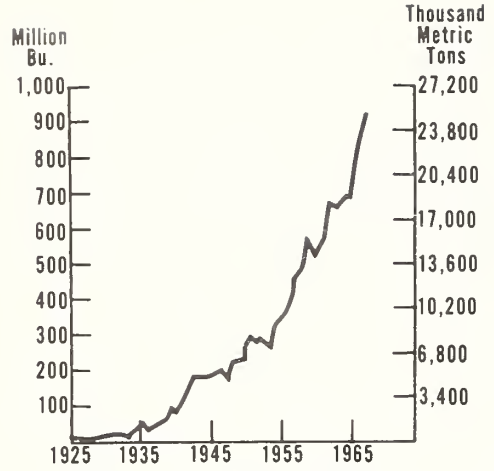

Figure 1. United States Soybean Production 1925 - 1966

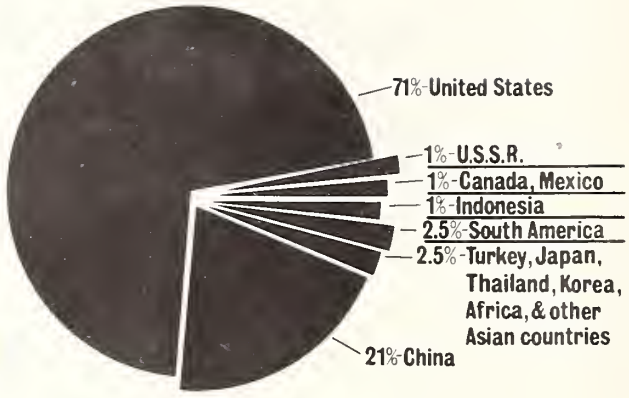

Figure 2. World Soybean Production - 1965

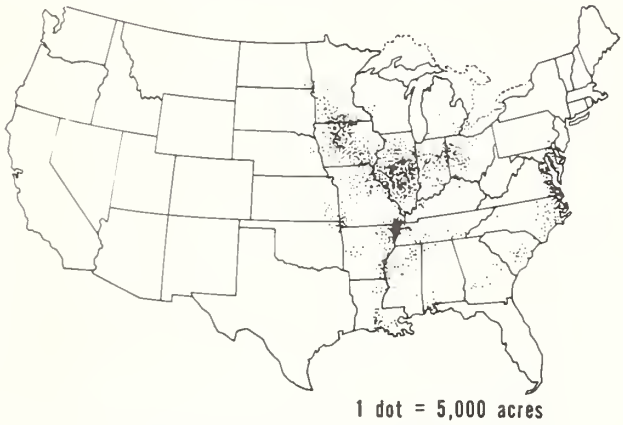

Figure 3. Soybeans Grown for all Purposes - 1949

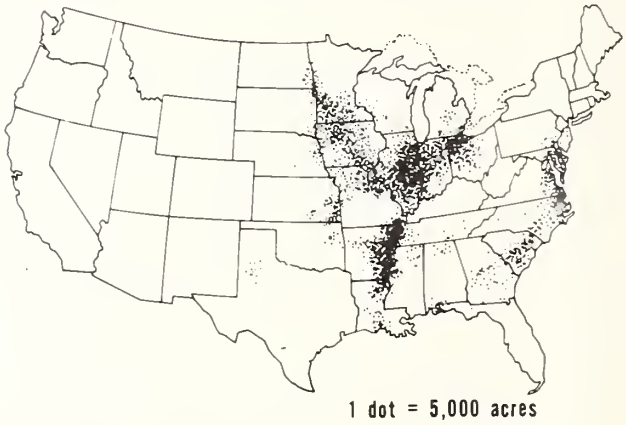

Figure 4. Soybeans Grown for all Purposes - 1959

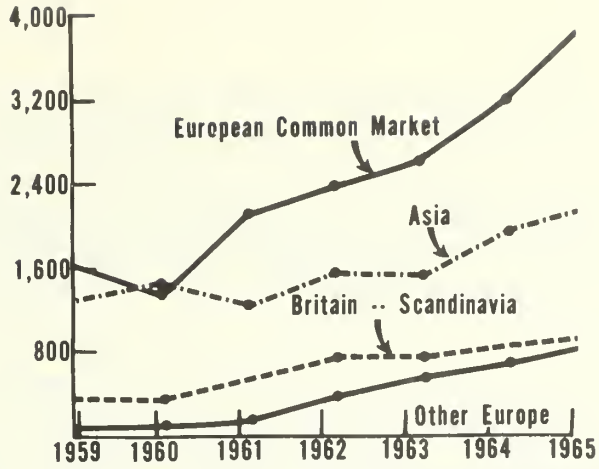

Figure 5. Annual U.S. Exports, Soybean Meal & Meal Equivalent, 1959 — 60 through 1964 — 65

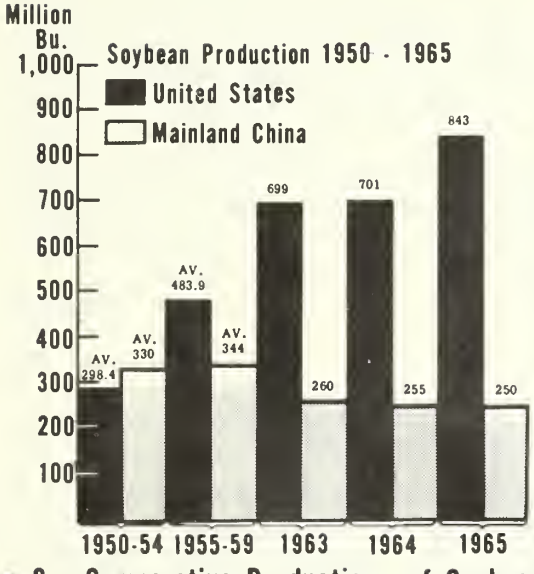

Figure 6. Comparative Production, of Soybeans, 1950 to 1965, of United States and Mainland China

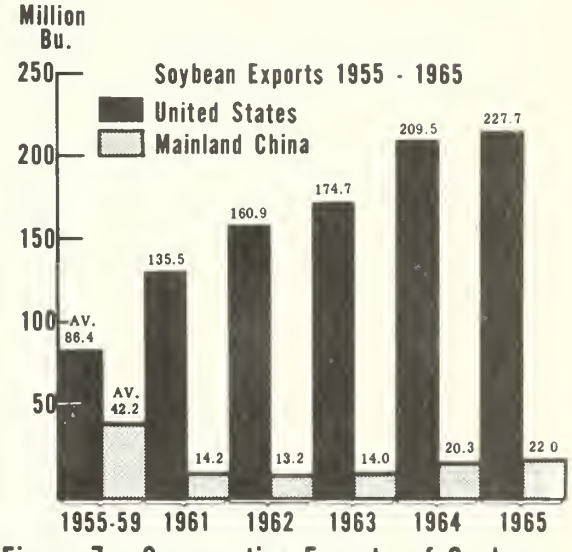

Figure 7. Comparative Exports of Soybeans, 1955 to 1965, of United States and Mainland China

SOYBEAN ACCEPTABILITY AND CONSUMER ADOPTABILITY IN RELATION TO FOOD HABITS IN DIFFERENT PARTS OF THE WORLD

S. S. De and J. S. Russell, Food and Agriculture Organization of the United Nations, Rome, Italy, and Leon Marie Andrè, FAO Liaison Officer and adviser to UNICEF /presented by Leon Marie Andrè/

The Chinese have a long tradition, going back to the pre-Christian era, for the use of the soybean. With centuries of experience, they have developed various methods for processing the soybean. Soybeans are grown as a food crop in China, Manchuria, Japan, and other countries of the Far East. The soybean has been introduced in other parts of the world but its uses are different than in the Far East. In the Eastern countries, the soybean is of value for its protein, while in the West it has vied for its oil. The soybean, in contrast with the common legumes, is consumed in different forms requiring different processing methods. The soybean is processed in two different ways: for oil and meal by expeller or solvent extraction, and for the protein by water extraction or treatment with fungus.

The main reason for the need of special processing of the soybean is due to the fact that it generally requires a long time for cooking to soften, and even then it may cause flatulence and diarrhea. A high proportion of the carbohydrate in the soybean is indigestible. It also contains a trypsin inhibitor which could not be removed easily by boiling the beans like pulses.

Traditional Soy Products in the Far East

Two types of processing have been developed in the Far East: one based on water extraction of soaked and ground beans (soy milk), and the other by the use of fungus to form fermented products, such as soya sauce, natto, miso, tempeh, etc. There is a general improvement in flavor and taste by fermentation. A variety of products is made from soybean milk such as bean curd, aburage (fried bean curd), koritofu (dried bean curd), and soy cheese.

Production and consumption of these products are given to illustrate their acceptability in different countries.

Soysauce

Soysauce is a popular seasoning in all Far Eastern countries and is exported in small amounts to Europe and the U.S.A. Large-scale factories have been established, and in Japan 60 percent of soysauce is produced in big plants. The product is used in small amounts and is of no practical value from nutritional considerations.

Soy milk

Soy milk has been known in Mainland China for centuries. It is mostly produced in the homes and sometimes on a cottage scale. Hot soy milk is used as a breakfast beverage in Mainland China, Japan, Taiwan (China), and Thailand. The product is generally popular with the local Chinese population. However, home production of soy milk for use as a beverage is rather limited. Soy milk is usually produced for production of bean curd. The first large-scale production of soy milk started in Hongkong in 1948. The sale of soy milk gradually increased and in 1965 another plant was established to meet the increasing demand of the colony. The present production is estimated to be about 120,000 bottles a day, highest for any soft drink sale in Hongkong. Plants have been established for soy milk in Singapore, Manila, and Bangkok. During the last 3 years, 12 small units for production of soy milk have been established in Taiwan (China), and more plants are expected to be built in the near future. The FAO/UNICEF assisted soy milk plant in Indonesia started operation in 1957, and in 1964 the production of soy milk powder was estimated to be about 1000 metric tons. Soy milk powder is also produced in Japan but mostly used for preparation of tofu. Attempts have been made in India for establishing soy milk plants, but no commercial plant has been established as yet. It seems that the population, accustomed to the taste of cow's milk, is not much in favor for the taste of soy milk. By blending the product with cow's milk or malted preparation, it may be possible to make it acceptable.

Bean curd

Bean curd is prepared by coagulating soy milk with calcium salts. In most of the Far Eastern countries it is a common item of food. The product is more popular with the local Chinese population than with the native population. In practically every market place in the Far East bean curd is sold and purchased in small quantities. In every small town in Thailand, Malaysia, and Indonesia there are small units for bean curd production. The product is more popular in Japan, Taiwan, and Korea. In Japan, there are thousands of bean curd manufacturers, mostly on a small scale but with modern equipment. There are few large-scale tofu manufacturers in Japan. In recent years, a process has been adopted in Japan in which the whole milk is coagulated into bean curd without loss of whey.

Tempeh

Tempeh is only produced in Indonesia on a cottage scale, and the technique of preparation is known only to certain families. Tempeh is a popular item of food. Every Indonesian household would like to buy tempeh if there is some money left after the purchase of rice. The product is hardly known in any country other than Malaysia, where a small plant has been established for consumption by the people emigrated from Sumatra.

Natto and miso

Natto and miso are produced only in Japan. Formerly, they were produced in the traditional way in the homes; but during the last decade large-scale plants have been established. Miso factory production is about two-thirds of the total production. Miso is used as soup and the average per capita consumption is estimated to be about 30 grams per day. These products have characteristic flavor and taste.

Roasted soy flour

This product is produced in small amounts in Japan and consumed with rice cake. There is hardly any information on the nutritive value of the product.

Kochu Chang

Kochu chang is produced in every household in Korea from mashed boiled beans which are hung in bags for 2 to 3 months. The product is broken up, dried, and ground. It is then mixed with ground red pepper and kept for some time before use.

Sprouted beans

Sprouted beans are sometimes sold in the markets of Far Eastern countries. They are eaten occasionally in the form of a salad.

There are a number of traditional soya products in the Far Eastern countries, but only one or two kinds of products are common to one country; such as tempeh in Indonesia, miso and natto in Japan, and kochu chang in Korea.

These traditional products have not been introduced in other countries, which may be due to the special skill required in their preparation and the characteristic flavor of these products. It can be concluded that fermented soy products are generally acceptable in the country of origin. Soy milk, particularly bean curd, is popular in all the Far Eastern countries.

Introduction in Other Countries

The soybean was introduced into the U.S.A. and Europe a long time ago. It became a commercial commodity in the present century in North America, Brazil, U.S.A., and a few European countries.

The increase in production of the soybean in the United States during the past 40 years is phenomenal. The amount produced in 1924 was approximately 5 million bushels, while the production rose to 702 million bushels in 1964, amounting to nearly 55 percent of the world production. Mainland China, including Manchuria, accounts for about 35 percent of the world total. Of the remainder, the only countries outside the traditional soybean-consuming countries of Indonesia, Japan, and Korea to produce any significant crop

were Brazil with 475,000 tons and the U.S.S.R. with 350,000 tons or a little over 1 percent each of the world total. There is a limited production in Cambodia, Taiwan (China), and Thailand in the Far East and in Italy, Yugoslavia, Rumania, Hungary, and Bulgaria in Europe.

In Africa, the soybean has been grown only in a comparatively limited area. It was introduced into the Union of South Africa in 1903, where there is still a small production. The Congo, Rwanda, Tanzania (Tanganyika), and Nigeria have also grown small amounts.

In Latin America, in addition to Brazil, small amounts are grown in Mexico, Colombia, Paraguay, and Argentina.

In the Near East, the soybean has so far not gained popularity. At present it is cultivated on a small scale in Turkey where estimated production over the period 1964-65 was 5,000 metric tons.

The soybean is grown in the United States principally for the value of its meal in livestock feed. Roughly 40 percent of the U. S. production has in recent years been exported, principally as raw beans to European countries and Japan. In Europe, the beans are extracted for livestock feed, the oil being used internally or re-exported to other countries within the same region. Most of the soybeans produced in Europe and Latin America are used for oil extraction. A part of the production from Africa is exported to the Far East. The world soybean production since the war has exhibited market expansion. This has been due mainly to obtaining meal for livestock feeding.

New Types of Products

In the U.S.A. and to some extent in the United Kingdom, processed soya products have been developed for a variety of uses. Although in the U.S.A. about 10 million tons of soy meal are used as feed, approximately 30,000 tons are utilized for food and industrial purposes. Types of new soy products introduced for human consumption are given below.

Defatted Soy Flour

Soy flour and soy grits were first prepared commercially in the early 1930's. These products are used for the following reasons:

1. To improve the storage qualities (shelf life) of bread and other bakery products.

2. To improve toasting qualities of bread.

3. To replace milk solids and other ingredients and to reduce the cost of production.

A supplementary food with soy grit base is produced in the United States and distributed by a voluntary organization to different parts of the world. During the last few years attempts have been made to introduce defatted soy flour in many parts of the world.

Full-Fat Soy Flour

Full-fat soy flour is produced for making food for infants allergic to milk.

Soya beverages of different types have been developed by the Soybean Council of America.

Formula No. 1. This product is suitable for feeding infants and is prepared from toasted full-fat soy flour mixed with skim milk, cane sugar, vitamins, and minerals.

Formula No. 2. This product is suitable for children and is prepared from toasted defatted soy flour, skim milk, cane sugar, etc.

Formula No. 1 is more stable in suspension than Formula No. 2.

High-protein soy soup. The product is prepared from toasted, defatted soy grits, skim milk, salt, potato starch, hydrolyzed protein, dehydrated onions, and additional seasoning.

Justification

In food deficit countries, the pressure on land is so much that production of animal foods could not be much increased. From an acre of land the protein yield from soybeans is more than five times that of beef.

With a view to increasing protein supply, cultivation of soybeans is desirable not only from the point of yield but also from a cost consideration which is illustrated in the following table:

Source	Protein cost[1/]		
	Dollars per lb.	Percent protein	Dollars per lb. protein
Beef	0.70	15.2	4.60
Pork	0.50	11.6	4.30
Poultry	0.30	20.0	1.50
Nonfat dry milk solids	0.145	35.6	0.41
Dry beans	0.08	23.1	0.35
Soybeans	0.05	34.9	0.14

1/ Soybean Digest, September 1965.

Attempted Introductions

Various attempts have been made in a number of countries to introduce soybeans in the local diet. In most cases trials were restricted to schools and orphanages, and the results were promising. But, commercial production was never started. Extensive studies were carried out by Indian Research Fund Association, but the results did not show any superiority of soybeans over common legumes of the country. The results, however, could not be considered conclusive as the variety used was not suitable for edible purposes; and the soybeans were cooked like pulses instead of the conventional methods used for processing soybeans. Soy milk was produced on a pilot-plant scale in India over a number of years for feeding to school children, army recruits, and in orphanages. There have been several proposals for establishment of a plant for producing soya milk in India, but there is no regular production as yet. Attempts have been made in a few countries in Africa for introduction of soy products without much success. The failures may be due to reasons mentioned later.

Negotiations are in progress for the introduction of modern processed soy products in India by importing a small amount from abroad and after determining acceptability, encouraging local production of soybeans and their processing. The approach is logical from best land use for production of a cheap source of protein; but there are various other factors such as incentive for farmers, agricultural adoptability, and consumer acceptance compared to local legumes.

Factors Involved in Adoptability

Introduction of any new type of soy product should be considered in relation to the existing traditional soy products produced and consumed in the region. The eating habits, cultural patterns, and marketing facilities are also equally important considerations for introduction of a new type of food. The product must possess organoleptic characteristics (taste, smell, color, texture, etc.) that fit the expectation of the consumer, and it should be presented in a form which could be easily incorporated in the local dishes or have resemblance to local foods and beverages. However, experience has shown that a new product though nutritionally perfect is unlikely to achieve acceptance automatically. The product needs to be promoted, and it goes without saying that it must be promoted effectively.

To be effective it cannot be a matter of guesswork, and objective prior consideration of all factors which underlie consumer choice is essential. The following principles will be a helpful starting point in indicating where to look for questions affecting the efficiency of a given promotion, be it for a protein-rich food or a tin of baked beans.

Consumer's requirements--It is based on fundamental consumer needs, attitudes, and interests.

One vital idea--It focuses one compelling idea that can establish a significant reason for trial.

The most persuasive idea--Choice and establishment of a single concept about the product in the consumer's mind.

These principles constitute the root of all good promotional schemes, but until the right message is isolated there is little point in considering how it should be put over.

It should be recognized that consumer decisions come as much from the heart as the head, and the product must live up to the expectations raised in consumers' hearts and heads by the promotion message.

The question remains whether the soybean can be successfully introduced in areas where it is at present relatively unknown; it is, therefore, a field wide open to investigation of the various factors involved. Introduction should be considered from agricultural and consumer adoptability aspects. The soybean adopts to a wide range of climate, temperature, and soil conditions. For introduction of soybeans, there should be a clear definition of the soybean varieties most suitable for the area involved and their uses.

Varieties of soybeans may be divided into three utilization groups: (1) commercial, (2) forage, and (3) vegetable. Varieties for commercial seed production are preferably yellow-seeded and are used for oil and meal. These varieties can also be utilized as forage if heavier rates of seeding are used. Vegetable varieties are those which have proved best for eating, as the green shelled and mature beans. These have a mild or nutty flavor and cook easily. Although a few black, brown, and bi-colored varieties have been found to have qualities superior to green shelled beans, the most suitable vegetable varieties are those with straw-yellow or olive-yellow (greenish) seed. The varieties used for processing and forage purposes usually do not cook easily and have a raw, beany flavor.

There is also a need for the development of special varieties of soybeans for a particular processing method to get products with a better flavor and nutritional quality. Although efforts are being made in Asia and the Far East for the selection of varieties suitable for particular soils and climatic conditions and to give increased yields, hardly any effort has been made to develop varieties to suit a processing method. Bean curd manufacturers in Japan found that most of the soybeans imported from the U.S. were not suitable as the yield of curd was low. Studies were undertaken

in the Northern Regional Research Laboratory of the U.S. Department of Agriculture for the selection of varieties, and some varieties are now imported for bean curd manufacturers. Most of the soybeans grown in the Far East are of a field type suitable for oil extraction. Only in the U.S.A. are some edible varieties of soybeans grown for salads and canning.

Consumer adoptability of a new type of processed soy product is easier in countries where the soybean is generally consumed in different traditional forms. As traditional products have characteristic flavors and taste, their introduction in other countries will be more difficult than the new processed soy flour or grits. Introduction of soy milk may be much easier as reported earlier. Soy products in the form of powder or grits, though generally acceptable, are rather difficult to be introduced in the local dishes. In countries where the noodle is commonly used, soya flour could be easily incorporated in it. In bakery products, 5 to 10 percent soya flour could be added easily. However, when a sufficient amount of soy products, such as full-fat flour or solvent-extracted flour are expected to be consumed, these products should be given in the form of beverage or soup to make them acceptable. Small-scale feeding trials have been carried out on soy flours and grits in Taiwan and Hongkong, and the products are acceptable; but large-scale feeding trials are required to determine the adoptability of these products by the population.

Introduction of the soybean will be rather difficult in countries where it is practically unknown and which have an abundant supply of acceptable vegetable protein sources, such as groundnut, chick pea, and mung bean. The soybean cannot replace easily grained legumes because of the difficulty of cooking and its beany taste. Special processing methods, as mentioned earlier, have to be introduced. Because of their low cost and high nutritive value, FAO recognizes that the increased use of soybeans for human consumption in appropriate developing countries is very desirable. It is now well recognized that the motives of the nutritionist and the factors that condition human acceptance of a new food are rarely the same--people just cannot be relied upon to eat things which are good for them.

It could be concluded that objective pre-evaluation of all factors that will condition human acceptance is essential before large-scale projects involving the introduction of new foods based on soya are undertaken. This will be even more important in countries where there is no established pattern of soya consumption.

SOYBEANS AS A SOURCE OF PROTEIN FOR HUMAN FEEDING IN LATIN AMERICA

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It is a well-established fact that most of the Latin American population suffers from protein deficiency, which is particularly prevalent and serious in children during the weaning and post-weaning period, that is, before 4 years of age. There are several reasons for the wide occurrence of this deficiency, one of which is the low availability and high prices of foods, which are adequate dietary sources of protein in quantity and in quality. This is particularly true for foods that can be used in the feeding of infants and small children. The remarks in this paper will be based on the experience with rural populations of Central America; however, it can safely be stated that the situation is similar for other areas or countries in Latin America.

Table 1.--Mean daily food consumption of Guatemalan Indian families in terms of edible portion (1962)[1/]

Food--grams per head	Town[2/] A	B	C
Milk and milk products[3/]	7	26	12
Eggs	7	6	5
Meat	20	24	17
Pulses	53	71	28
Fresh vegetables	84	64	130
Fruits	40	30	18
Tubers	4	5	9
Cereals[4/]	425	428	430
Sugar	48	58	52
Fat	2	4	1
Coffee	7	6	5

1/ Taken from: Flores and coworkers, Brit. J. Nut. 18: 281, 1964.

2/ Town A: Sta. Catarina Barahona; Town B: Sta. Ma. Cauqué; Town C: Sta. Cruz Balanya.

3/ Expressed as liquid milk.

4/ Dry weight basis.

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Table 1 shows the average composition of rural diets of three rural towns of Guatemala (1). It can be seen that consumption of cereal grains and other carbohydrate sources is large. Although some bread and rice are also consumed, the main cereal grain is corn. Consumption of beans is below what would be needed to improve the protein quality of the cereal grains. INCAP studies (2) have indicated that the best protein balance with corn and beans is obtained when they are consumed in the ratio of 2.6 parts of corn to 1 part of beans. The ratio in Towns A, B, and C is 8, 6, and 15 parts corn to 1 part beans, respectively. Consumption of animal products is also lower than desired. Furthermore, the average figures given are the result of sporadic consumption of these products by only some of the subjects studied.

Table 2.--Mean daily intake of calories and protein by Guatemalan-Indian families (1962)[1/]

	Mean daily intake per head in: Town A	Town B	Town C
Calories, number	2054	2163	1938
Total protein, grams	59.0	62.7	53.5
Animal protein, grams	6.2	6.3	4.5
Protein score	61	56	51

[1/] Taken from: Flores and coworkers, British J. Nut. 18: 281, 1964; J. Am. Diet. Assoc. 48: 480, 1966.

Table 2 shows that total protein intake appears to satisfy the needs for protein for the adult population; however, the protein scores based on tryptophan content show that the quality of such diets is very low. Even lower quality values would be obtained if the net protein utilization of such diets is considered, that is, when the protein intake is corrected for both digestibility and biological value. Although the percent protein digestibility is not available, it can be estimated to be no greater than 75 percent. Because of the large amounts of cereals consumed, such diets are low in lysine content and usually tryptophan and methionine are also limiting amino acids, resulting therefore in diets of low biological value.

Table 3 shows the average daily food intake of preschool children in the same three villages in Guatemala (3). Again, it is striking to see the excessively large intakes of cereal grains, mainly corn, as compared to animal protein sources.

Table 3.--Foods consumed per child per day in three rural towns in Guatamala (3 to < 4 years)[1/]

	Foods consumed per child per day in: Town A	Town B	Town C
Milk and milk products, grams[2/]	28	23	14
Eggs, grams	4	4	2
Beef, grams	10	11	4
Pulses, grams	24	26	15
Fresh vegetables, grams	41	30	48
Fruits, grams	68	21	31
Cereals, grams	281	295	277
Potatoes, grams	3	2	3
Sugar, grams	37	33	33
Fat, grams	1	1	--
Protein, percent (dry wt. basis)	11.9	12.3	11.5

[1/] Taken from: Flores and coworkers, J. Amer. Diet. Assoc. 48: 480, 1966.

[2/] Expressed as liquid milk.

Leguminous seeds are also consumed in very low amounts. As with the adult diets the amount of beans consumed is too low for the amounts of cereal grains ingested by the children. The crude protein concentration of these diets on a dry weight basis is only 12.0 percent, equal to or not much higher than that of corn. Diets for children of these same age groups should contain not less than 18 percent high quality protein on a dry weight basis.

Table 4 shows the mean intake of calories and protein, and the percent of the recommended allowance for both nutrients, as well as the protein score based on tryptophan values and protein efficiency ratio (PER). From these figures it can be seen that the quality of such diets is very poor and utilized very inefficiently. The total protein in these diets is deficient in lysine, methionine, and tryptophan. The problem is more complicated by insufficient intake of calories which will further interfere with protein utilization.

It is evident, therefore, that adequate dietary sources of protein are needed to correct both the concentration and the quality of this nutrient in such diets. Animal products, particularly milk, are not available and have other limitations for their wider use; the possibility of using available and less expensive sources of protein of vegetable origin is therefore of interest.

Table 4.--Mean intake per child per day of calories and protein in the three towns (3 to < 4 years)[1/]

	Town A	Town B	Town C
Calories, number	1065	978	847
Recommended allowance, percent	93	86	74
Protein total, grams	32.1	27.1	21.9
Animal, grams	7.9	3.5	1.8
Recommended allowance, percent	80	68	55
Protein score	64	58	51
Protein efficiency ratio (PER)	1.64	1.32	1.13

[1/] Taken from: Flores and coworkers, J. Amer. Diet. Assn. 48: 480, 1966.
Braham and coworkers, INCAP studies.

Cottonseed, when properly processed, has served as a good source of protein suitable for human feeding, and vegetable protein mixtures based on cottonseed protein concentrate have been developed, tested, and commercially produced in Central America and Colombia (4, 5). Although cottonseed has been and still is a source of oil and of protein for both animal and lately for human nutrition, the need for other sources is extremely high.

Soybeans can provide the need for protein for both the human and animal population as well as to supply the need for oil, which is also in demand in Latin America.

Soybean production in Latin America is limited to only a few countries as shown in Table 5. Production in Brazil reached 12.7 million bushels in 1962; 11 million bushels in 1963; and 11 million bushels in 1964. In Mexico, Colombia, and Argentina production of soybeans during the last 10 years has increased gradually; however, it is still low. Mexico's production reached 1.3 million bushels in 1963 and increased to almost 2.5 million bushels in 1964, while in Colombia production exceeded 1.4 million bushels in 1963 and increased to over 1.8 million bushels in 1964. In Argentina, production was slightly over 500 thousand bushels in 1964 (6).

Although the production figures are low, yields per acre are comparable to those obtained in the United States. The yields reported vary from 1,200 to 2,000 kg./ha. (18 to 30 bu./acre). Lately, other countries besides

Table 5.--Soybean production in Latin America
(million bushels)

Country	Soybean production 1964	1965
Brazil	11.2	16.6
Mexico	1.3	2.5
Colombia	1.4	1.8
Argentina	0.5	< 0.4

Mexico, Colombia, Brazil, and Argentina are selecting varieties adaptable to the area to replace part of cotton and to serve as an auxiliary crop. In Guatemala, for example, 22 varieties are being tested and yields as high as 2000 kg./ha. have been produced from experimental plots.

Utilization of Soybean Flour. INCAP Studies

During the last 4 or 5 years, soybean flour has been tested at INCAP as a protein supplement to lime-treated corn, which is used in the form of tortillas in several Latin American countries (7). Similarly, soybean flour has been used to enrich cereal gruels, which are very popular among the human population, both young and adult (8, 9). Results of these studies are summarized in Table 6, where it can be seen that 6 to 10 percent of soybean flour increase the protein value of lime-treated corn flour, rice flour, and both whole and white wheat flour. It is obvious that besides increasing protein quality, the quantity of protein is also increased, which is a needed factor in most diets of populations of low socio-economic condition.

Table 6.--Supplementation of cereal grains with soybean flour[1/]

Soybean flour added, percent	Protein Efficiency Ratio: Lime-treated corn	Whole wheat	Wheat flour	Rice
none	1.00	1.62	0.86	1.66
6	--	1.89	--	--
8	2.25	--	--	2.88
10	--	--	2.01	--

1/ INCAP studies.

Several tests have been carried out to determine if the amount of soybean flour added would affect the texture and flavor of the tortilla produced from enriched lime-treated corn and of whole wheat bread. The result of these studies indicated that flavor and texture did not change significantly and the foods prepared were very well accepted. Very little use has been made of these observations, first, because of the low availability of soybean flour, and second, because at least in the case of corn, this cereal is processed at home for the preparation of "tortillas." Studies have also been carried out to test the possibility of including soybeans together with corn in the home preparation of tortillas. The results were also successful but lack of soybeans, education, and possibly other factors have also prevented the utilization of this information.

Table 7.--Composition of INCAP vegetable mixtures 14 and 15

Ingredient	Mixture 14	Mixture 15
Soybean flour, percent	38	19
Cottonseed flour, percent	--	19
Corn flour, percent	58	58
Torula yeast, percent	3	3
Calcium carbonate, percent	1	1
Vitamin A, Intl. Units	4500	4500
Protein content, percent	26	26
Protein Efficiency Ratio	2.56	2.21

INCAP studies.

Better success has been achieved in the development of high protein vegetable mixtures based on soybean flour and corn and of soybean, cottonseed flour, and corn. Two such mixtures have been developed and tested in experimental animals and children, and one mixture is already in commercial production (5, 10). The composition of INCAP formulas 14 and 15 is shown in Table 7. One contains 38 percent soybean flour while the other contains 19 percent. The protein content is around 26 percent for both and their PER is 2.56 and 2.21, respectively. Table 8 shows that the protein quality of mixture 14 can be increased significantly by adding 0.2 percent methionine, while the addition of 0.1 percent lysine and 0.2 percent methionine to mixture 15 caused also a significant increase in PER approaching the value of casein. The addition of 16 and 30 percent of skim milk will result in similar PER values as those obtained by adding the respective limiting amino acids.

Table 8.--Amino acid supplementation of mixtures 14 and 15[1]

Formula	Amino acids added	PER
Mixture 14	none	2.56
	0.2 percent DL-Methionine	2.93
	0.2 percent each of methionine, lysine, threonine	3.39
Mixture 15	none	2.22
	0.2 percent Methionine + 0.1 percent lysine	2.68
Casein		2.87

[1] INCAP studies.

As indicated before, these two mixtures have been tested in children (11). The results are summarized in Table 9. Calculations from the regression lines showed that the true protein digestibility and biological value (BV) were 91.8 and 78.6, respectively, for mixture 14 as compared to 92.0 and 80.6 for skim milk. The plot indicates that 92 mg. of N from mixture 14 are needed for nitrogen equilibrium as compared to 79 for milk.

Table 9.--Relationships between NI and NA to NR in children fed mixture 14 and mixture 15[1]

Protein	Regression equation	Value of NI for NR=0, mg. N/kg./day
Mixture 14	NR = -53.8 + 0.586 NI	92
	NR = -37.7 + 0.621 NA	--
Mixture 15	NR = -48.0 + 0.426 NI	113
	NR = -34.4 + 0.474 NA	--
Skim milk	NR = -50.7 + 0.640 NI	79
	NR = -39.2 + 0.730 NA	--

[1] NI = Nitrogen Intake; NA = Nitrogen Absorbed; NR = Nitrogen Retention.

With respect to mixture 15, true protein digestibility and BV were 88.7 and 71.9, respectively. With this mixture, 113 mg. of N gave nitrogen equilibrium. The data indicates mixture 14 to be superior nutritionally to mixture 15. Mixture 15 is already being produced commercially in Colombia and INCAP is making arrangements for mixture 14 to be commercially produced in Brazil.

Additional studies have been carried out to develop mixtures using full-fat soybean flour. Using the values for the optimum combination between corn and soybean protein found while developing mixture 14 (10), and using the method employed for the preparation of lime-treated corn, mixtures with full-fat soybean flour have been developed. The method used consisted in cooking corn and soybeans together in lime water, followed by drying with or without toasting. Such mixtures, prepared with different proportions of corn and soybeans, have been tested in experimental animals (12). Representative results are shown in Table 10. It can be seen that they have a high nutritive value as compared to casein. The growth of the animals was normal and food intake was as high as that from casein indicating that the lime cooking process is capable, if carried out correctly, of destroying the trypsin inhibitors present in soybeans.

Table 10.--Protein quality of full-fat soybean flour-corn mixtures

Protein distribution in mixture	Average weight gain, grams[1]	PER
100 percent corn protein	12	0.69
50 percent corn protein + 50 percent soybean protein	81	2.08
40 percent corn protein + 60 percent soybean protein	91	2.54
30 percent corn protein + 70 percent soybean protein	99	2.37
100 percent soybean protein	101	2.03
INCAP mixture 14	80	2.48
Casein	120	2.87

[1] INCAP studies, basis 28 days.

The results presented in this paper indicate that the diets of rural populations in Latin America, for both the young and the adult, provide relatively low amounts of proteins and that this is usually of very poor quality. These diets can be improved only if intake of good quality proteins is increased. Animal products are still in very short supply, expensive and have other limitations in their use due to various socio-economic and cultural factors. Therefore, we cannot depend upon them to supply both the quantity and quality of protein needed; other sources must be found and utilized. Soybeans can provide such needed protein. Data was also presented in how soybean flour can improve the protein quality of cereal grains and of the work of INCAP in developing and testing vegetable protein mixtures based on soybeans. It is believed that the cultivation and interest in soybeans is to increase in the near future in all Latin America.

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SPECIFIC PROTEIN DEFICIENCIES AND NEEDS IN AFRICA

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Introduction

Geography

Tropical Africa divides geographically into West Africa, and East and Southern Africa. Three ecological zones are obvious in West Africa--the savanna immediately south of the Sahara, the forest belt, and the coastal strip. The savanna has only one rainy season, and there is therefore only one major crop a year. Millets and sorghums are the main cereals produced, but yams and maize are becoming significant. Many wild and cultivated vegetables and greens are consumed, as are groundnuts, pulses, and legumes. Theoretically, the diets of this zone are well-balanced. However, storage difficulties and periodic failure of the rains make foods short at certain times of the year. Undernutrition is, therefore, the major nutritional difficulty in this zone.

The forest belt has more rainfall--usually a major season and a minor season. Plantains, bananas, cassava, and yams are the main crops that form the basis of the diet. Vegetables, such as tomatoes, okra, and spinach, are also used. Peas and beans are consumed only in small quantities. Animal products are in very short supply, and they are used largely as flavoring. It is in this belt that one sees the highest incidence of almost pure protein-deficiency conditions. The coastal belt produces maize, vegetables, and fish; and the usual diet is, therefore, reasonably well-balanced.

The East and Southern regions are mainly of savanna-type vegetation, with wooded areas on the highlands and around the lakes. In the grasslands, maize is the major food crop in the whole region. Green vegetables and pulses are used in relishes. Animals, even where kept in large numbers, do not materially add to the diet (except in some very restricted areas) because live animals count as wealth. In the woodland areas, plantains and cassava are extensively used for food.

Demography

The population of the whole of Africa is estimated to reach 300 million by 1970. The area below the Sahara (excluding the Union of South Africa) will then have a population of 200 million. This population is estimated to be growing at an annual rate of about 2 percent per annum, ranging from 1.8 percent in the drier parts to 2.9 percent in countries like Ghana and Nigeria. This high rate of demographic expansion means there is a large childhood population in all the countries. In many areas 45 percent of the population is under 15 years of age, and 20 percent is less than 6 years old. This in

itself poses a serious nutrition problem because the large group of children, though nonproductive, requires even more and better food for their sizes than the adults.

The Protein Problem

Protein-calorie deficiency is now known to be one of the most widespread and serious hazards of life and health to young children in practically the whole of tropical Africa. The condition is most often found among children from about 6 months to 5 years old either by itself or in combination with various febrile infections and is responsible for a very large proportion of deaths. It is too well recognized to merit discussion here. Food balance sheets have been produced for various countries in Africa which would seem to suggest that many countries in the region produce enough protein foods for their estimated needs. However, clinical and other surveys have proved that deficiency exists; and explanations for these deficiencies give the background to the whole problem.

Causes of the Deficiencies

Although actual production figures in terms of available proteins may be high, regional distribution may be so poor that some areas may be short. Burgess and Dean (1962)[1] found in Uganda that in spite of reasonable quantities of animal foods in Uganda as a whole the Baganda had very little of these. The actual types of foods may have proteins that are qualitatively not very good. Much of the proteins come from cereals, especially maize, millet, and sorghums, and in the wetter areas from root crops and starchy fruits. The proteins from cereal foods are usually lacking in one or more essential amino acids that restrict their utilization. Extreme polishing (white maize flour in East and Central Africa) may diminish the protein content and quality considerably. The starchy roots and tubers (yams and cassava) as well as starchy fruits, such as plantains and bananas, have protein content from 0.5 to 2 percent and are generally deficient in more than one amino acid. Storage, marketing, and processing are all so rudimentary that much of the food (variously estimated from 10 to 30 percent of the total produced) does not reach human mouths at all. In those areas where a money economy is getting established, some groups have become too poor to afford those foods which would supply the needed proteins. This is true of the lower paid elements in towns and the new immigrants. Plantation workers in areas devoted to cash crops also fare poorly.

Even where enough protein enters the family menu the distribution may be such that the children may not have their fair share. First of all, it is not generally realized that for his size a child needs more of everything than an adult. Taboos and food avoidances for health and other reasons are

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[1] East Africa Medical Journal 39(7): July 1962 [Special number].

important. Generally, foods like fish, meat, and eggs (even when no taboos or avoidances exist) are of such high prestige as to be considered primarily adult food. There are households in which children have no meat or fish at all. Usually the meal is a starchy root or cereal vegetable, plus a relish or side dish made up of vegetables with small amounts of legumes and pulses. The order of meals requires the menfolk to eat first; and by the time the children and women have had theirs, the relish may be all but exhausted. There is, therefore, not only maldistribution of the total protein rich foods but, and even worse, discrimination for the biologically more complete animal protein foods.

Weaning practices themselves are such as to make the child eat badly. Weaning is generally sudden and drastic, and often it is undertaken because the mother is pregnant. The child is weaned on to a starchy gruel and deprived of the little mother's milk it has been having. It may be pushed on to an aunt or grandmother. The emotional trauma of such a child may lead to some depression of his appetite. Finally, infections of all types are common and they tend to affect the food intake and nutritional state of the child adversely. Over 30 percent of all cases of protein-calorie malnutrition seen in Accra in 1962-63 have had measles 2 to 6 weeks prior to admission. As soon as a child gets a fever or diarrhea, most solid foods are withdrawn; and it may be given various purges as treatment. All these help to make any infective illness affect the nutrition of an African child at about the time of weaning very adversely.

It is possible, in addition, that because of these problems of intrafamily distribution what is considered as "safe allowances" may have to be altered to reflect the possibility of male adults having their fill before anyone else. In countries with 20 percent or more of the population being under 5 years, it may, therefore, be necessary to increase the national requirement considerably to reflect this fact.

The Extent of Protein-Calorie Deficiency in Africa

Many growth studies have been made in tropical Africa, and these tend to show that the African child grows very well from birth till about 6 months (this is the time when he is on breast). From 6 months through 4 years, there is retardation of growth. This corresponds to the period of greatest incidence of protein-calorie deficiency. The actual prevalance of kwashiorkor in children varies from 2 percent or less in the more cereal-eating communities of Senegal to 2 to 9 percent in the forest belts of Ghana and Nigeria. With a death rate of 20 to 50 percent such a disease load will result in 5,000 deaths per 1 million population per annum and will account for 15 to 20 percent of all deaths under 5 years old. The extent of this problem is not generally appreciated in the countries concerned, and even today there are countries in the region whose mortality statistics do not show much protein-calorie malnutrition.

These survey data include only florid cases, but when growth retardation and hair changes alone are used as diagnostic criteria then figures of 15 percent (in Ghana) to 50 percent in some surveys in Senegal are obtained.

Attempts are being made to illustrate the extent of this problem by the use of such mortality statistics as there are. Whereas the infant mortality rate is about five times that of the developed countries, the preschool child mortality rate is about 40 to 50 times. Many workers are reasonably agreed that this big difference is due in large measure to protein-calorie malnutrition.

There have been very few actual food consumption figures for children. From Ghana there were the findings of Davey:[1/]

Nutrients Value of Children's Diets

Area	Age years	Children number	Calories		Protein	
			Number	Percent of requirement	Grams	Percent of requirement
Forest	1-2	4	828	69	18.2	46
do	2-3	7	964	74	21.8	48
do	3-4	15	941	67	19.7	36
Savanna (dry)	1-2	2	804	67	20.7	52
do	2-3	5	778	60	24.9	54
do	3-4	18	1192	85	42.5	80
do (moist)	2-4	2	1509	111	53.8	107

1/ National Food and Nutrition Survey 1961-62. Mimeographed report of National Food and Nutrition Board.

These findings have shown that children have, on the whole, anything from under 40 to 80 percent only of their estimated protein requirements.

Cost of Protein Foods

The main foods supplying protein are:

Food group	Protein, percent	Protein/1000 cal., grams	Cost of 10 grams protein in Ghana Pesewas[1]	Cost of 100 cal. in Ghana Pesewas
Millet	9.7	28.5	2.2 (3.7)	0.7
Sorghum	10.1	29.6	1.6 (2.7)	0.5
Maize	9.5	27.9	2 (5)	0.5
Yam	2.1	23.3	5 (25)	1
Cassava	0.9	8.2	6 (30)	0.5
Fresh fish:				
fatty	10	111.1		
nonfatty	8.6	180	3 (4.5)	4.5
Meat (beef)	15.2	100	7 (9)	6
Beans and pulses	22.1	65.7	1.5 (3)	1
Eggs	11	73.3	7 (7)	8

[1] Figures in parentheses are cost of 10 grams of fully utilizable protein as taken from Net Protein Utilization (NPU) figures of Protein Requirement (FAO).

The protein-rich foods, with the exception of meat, provide 10 g. fully utilizable proteins much more cheaply than all other foods except the cereals.

It is obvious from these that were money for protein the sole consideration people could be advised to buy the better class proteins. However, the first essential in the human diet is calories and their cost. The richer protein sources of food are not so readily available. In most of tropical Africa milk has to be imported for foreign exchange which is required for development investment. For the family, a given food budget must provide enough to "satisfy," so the food budget has to be divided accordingly, e.g., of every 100 cents spent on food in Ghana (1961):

35 cents goes for cereal and starch roots;
40 cents goes for animal foods;
5 cents goes for beans and other legumes;
20 cents goes for vegetables, oil, sugar, etc.

It must be stated here that the cash proportion on cereals is small because in most of the rural areas practically no money is spent on the staples. Animal foods are expensive.

Attempts at Solution

Specific or Direct

Clinical--Identification and treatment of cases suffering from protein deficiency and measures to ensure that those cured remain free would be essential. Specific schemes for education and prevention would include supplementary feeding schemes using milk, soya protein, press cakes, etc. Rehabilitation centers for teaching mothers what to do within their financial and educational means would be important. Perhaps the single most important direct measure required is the development of a cheap weaning food. Various efforts are going into this:

Incaparina Mixture No. 9

	Percent
Corn masa	28
Sorghum	28
Cottonseed flour	38
Dehydrated leaf meal	3
Calcium carbonate	1 1/

1/ With added vitamin A.

Mixture Used by Dr. Dean in Uganda as a Biscuit for School Children

	Percent
Dried skim milk	15
Sucrose	12
Cottonseed oil	6
Maize flour	26
Peanuts	41

Mixture by Dr. Bradfield in Peru

	Percent
Cottonseed flour	30
Quinuia	10
Habas	10
Achita	10
Alfalfa leaf meal	2
Torula yeast	2
Wheat flour	35

In Nigeria, Arlac is being tried but another effort is being made to enrich the basic staple flour with enough satisfactory protein food to make it suitable in the traditional form. Cassava and maize flour are being enriched with soya flour. Couscous (millet and sorghum) is being enriched with groundnut in Senegal.

Long-term and Nondirect

The planning and development of better agriculture so that the actual food and nutrition problems will receive due attention is very much needed.

In far too many countries pulses and legumes, which are a good cheap source of protein, are produced and consumed in small quantities only. The selection of right varieties and their large-scale propagation would help. Poultry production is now a reasonably exact science, and many countries in Africa have demonstrated in recent years just how relatively easy it is to establish good poultry schemes. One such scheme in Ghana was able to produce broilers at about $1.40 a bird and egg prices were about halved within a couple of years. However, difficulties of producing feed at reasonable prices have altered the situation badly.

Fishing (both sea and fresh water) is receiving much attention and many areas are increasing their catches rather rapidly. Although much effort is going into dairy industries in many parts of the continent, the present writer does not see much immediate result in terms of reasonably priced dairy produce for most of the continent in the near future. Some areas in East Africa, such as Kenya, Northern Tanzania, and parts of Uganda may prove exceptions.

Some good schemes have, however, folded up because distribution and marketing support have been weak. The encouragement for producers to produce more and useful foods will only be successful if the farmers see the cash value for their efforts rather quickly.

Conclusion

The vastness of the protein-deficiency problems in Africa has to be seen to be believed. Children in the preschool period illustrate this most readily, and it is therefore useful to think of this age group in any plans for immediate impact. It would appear as if the development of a cheap readily accepted weanling food is the first priority. Such a food naturally is to be based on the local staple plus some good protein-rich source of food. The pulses and legumes are the foods for obvious trial, and among these the soybean has a special place. Soybeans grow relatively easily and widely and much of the technology is known. Investigations for applying such known technology for the immediate needs are urgently required. Efforts are already being made, but these will have to be

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strengthened. Apart from such lines of approach, the reorientation of peasant agriculture to include some better appreciation of the fundamental food requirements of the human would help. But far and away the most likely long-term solution is the rapidly guided transition of the whole economy from subsistence to market with the planners taking care to avoid many of the known problems of such transition.

PROTEIN NEEDS AND ITS DEFICIENCY IN ASIA

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We have assembled here under the shadow of a great catastrophe, perhaps the greatest the human race has ever faced. It is the population explosion in which the population is doubling itself every 30 years, a nightmarish prospect of having 7 billion mouths to feed by the year 2000 A.D. in a world which with half that number has already hungry millions. It is a catastrophe that could destroy humanity, described in the holy Koran as the best of creation (Ashraful Mukhlukat), if not the biological species, Homo sapiens, unless science steps in, in a big way, to produce more and more food for the increasing millions and to deaccelerate the rate of increase of their number. Even though I am one who comes from an area where the explosion would have its severest effect, I anticipate that the shadow will be lifted and that humanity will survive through concerted and timely action of individuals and organizations, such as those responsible for this symposium, and cooperation of peoples and governments all over the world. It is through faith and confidence in the destiny of man that we will find knowledge and wisdom to discover ways and means to our survival.

Through the phenomenal development in the science of nutrition and allied sciences in the last few decades, we are able to assess the precise needs of the human body in terms of nutrients and thus isolate the needful from the superfluous; and through improved knowledge of food sciences, we also know how these nutrients are to be produced in maximum quantity with utmost economy. Unfortunately, the acquisition of knowledge and its application are the lowest in those areas of the world such as the developing nations of Asia, where they are most needed and where more than half of the world's population live.

I wonder how seriously he was impressed when Berzelius in his letter to Mülder dated July 10, 1838, first introduced the term protein, as derived from Greek, Proteios, meaning "of first importance" to describe some nitrogenous complex substances present in plants and animals. We now realize there could be no name more appropriate than this, for proteins are of first importance not only to make the bulk of the tissues, but also to make such essential compounds as enzymes, certain hormones, and antibodies which sustain the phenomenon of life.

The overwhelming mass of humanity that lives in Asia are in dire poverty. A study of the distribution of calorie supply in relation to the requirement of calories of the population (Third World Food Survey, Freedom from Hunger Campaign, Basic Study No. 11) has shown that at least one-fifth and

possibly more of the people in this region go hungry. And, if malnutrition due to poor quality of the diet is also considered, the situation is far worse.

In recent years, quite a few nutrition surveys have been carried out in the countries of this region under the auspices of the Interdepartmental Committee on Nutrition for National Development (ICNND), now Nutrition Section, Office of International Research, National Institutes of Health, headed by its able Director, A. E. Schaefer, who considers that protein-calorie undernutrition is the most important nutritional problem impeding health and economic development of this area (Second Far East Symposium on Nutrition, 1964). In 1965, a joint FAO/WHO expert committee on nutrition made the recommendations shown in Table 1 with regard to the protein requirements. The most important thing to note in this table is the quality versus quantity relationship. A quantity of protein of NPU=100 is equivalent to double the amount of protein of NPU=50. This is of great consequence to the peoples of Asia whose protein (whatever amount they get) is mostly derived from plant sources, especially cereals. The Net Protein Utilization (NPU) of some common plant sources used in Asia along with NPU of some animal sources (Protein Requirements, FAO Nutrition Meetings Report Series No. 37, page 48, 1965) are shown below:

Egg=100

Food	NPU
Rice	57 (lysine)[1/]
Corn meal	55 (tryptophan)
Millet	56 (lysine)
Kaoliang	56 (lysine)
White flour	52 (lysine)
Groundnut flour	48 (sulphur-containing essential amino acids)
Wheat gluten	37 (lysine)
Soy flour	56 (sulphur-containing essential amino acids)
Sesame seed	56 (lysine)
Sunflower seed	65 (lysine)
Cottonseed meal	66 (sulphur-containing essential amino acids)
Peas	44 (sulphur-containing essential amino acids)
Milk (cow's)	75
Beef muscle	80
Pork tenderloin	84
Fish	83 (tryptophan)

[1/] The names in parentheses are those of the limiting amino acids.

Table 1.-- Protein requirements of children and adults and the effect of protein quality

Age	Grams per kilogram body weight per day																	
	NPU = 100			NPU = 90			NPU = 80			NPU = 70			NPU = 60			NPU = 50		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Infants (mths)																		
0- 3			2.3															
3- 6			1.8															
6- 9			1.5															
9-12			1.2															
Children (yrs)																		
1- 3[1/]	0.70	0.88	1.06	0.78	0.98	1.18	0.88	1.10	1.32	1.00	1.25	1.50	1.17	1.46	1.75	1.41	1.76	2.11
4- 6	0.65	0.81	0.97	0.72	0.90	1.08	0.81	1.01	1.21	0.93	1.16	1.39	1.07	1.34	1.61	1.30	1.62	1.94
7- 9	0.62	0.77	0.92	0.69	0.86	1.03	0.77	0.96	1.15	0.88	1.10	1.32	1.02	1.28	1.54	1.23	1.54	1.85
10-12	0.58	0.72	0.86	0.64	0.80	0.96	0.72	0.90	1.08	0.82	1.03	1.24	0.96	1.20	1.44	1.15	1.44	1.73
Adolescents																		
13-15	0.56	0.70	0.84	0.62	0.78	0.94	0.70	0.88	1.06	0.80	1.00	1.20	0.93	1.16	1.39	1.12	1.40	1.68
16-19	0.51	0.64	0.77	0.57	0.71	0.85	0.64	0.80	0.96	0.74	0.92	1.10	0.85	1.06	1.27	1.02	1.28	1.54
Adults	0.47	0.59	0.71	0.53	0.66	0.79	0.59	0.74	0.89	0.67	0.84	1.01	0.78	0.98	1.18	0.94	1.18	1.42

I Protein intakes considered inadequate for all but a very small fraction (2.5%) of the population.
II Estimated average protein requirement of a population.
III Protein intake considered adequate for all but a very small fraction (2.5%) of the population.

1/ The intake capacity of children of this age may not allow the provision of adequate protein of Net Protein Utilization (NPU) below 60.

The poverty of protein in the diet of the Asians is obvious from the fact that the bulk of their food is cereal, a poor source of protein. Table 2 illustrates the dominance of cereals in our diet (A. E. Schaefer, Second Far East Nutrition Symposium, 1964).

Table 2.--Consumption of cereals in Far Eastern countries

Country	Calories from cereals, percent
Thailand	65.7
Burma	76.0
Malaya	63.3
Indonesia	55.8
Philippines	60.3
Taiwan	64.5
South Korea	79.7
Japan	66.7
East Pakistan[1/]	85.0

[1/] East Pakistan Nutrition Survey, 1966.

The status of the protein in the diet of Asians is also indicated in Table 3, where the total quantity of protein and contribution therein of animal sources are shown (ICNND Survey report).

Table 3.--Protein consumption in Asian countries

Country	Total protein, grams	Animal, percent
Asia	56.0	11.4
India	53.0	11.1
East Pakistan	57.5	13.0
Vietnam	69.6	33.0
Burma	54.9	19.0
Thailand	49.1	31.0
Ceylon	41.0	22.0
Philippines	47.7	30.0
Malaya	75.5	33.0
Japan	69.7	39.0
United Kingdom	88.0	61.4
United States	72.0	91.6

The second most important point in the report of the joint FAO/WHO expert committee is in regard to the requirements of children and pregnant and lactating women. It would be seen that the requirement of protein of a child of say 1 to 3 years per kilogram of body weight is about 1.5 times that of an adult (0.81 g. against 0.54 g.). In a country where protein is poor both in quantity and quality, the need of those, namely the children, who require it most is most likely to suffer. That is exactly the situation in Asia, where protein malnutrition shows up in a disastrous way among the children.

Infants, children, and adolescents constitute a large section of the population of Asia; and along with their mothers they are highly vulnerable to malnutrition. The composition of population of Far Eastern countries is shown below:

Far Eastern countries[1]		East Pakistan[2]	
Age	Percent	Age	Percent
0 - 4	15.0	0 - 4	18.4
5 -14	23.2	5 - 9	18.9
15 -24	18.2	10 -14	9.1
25 -44	26.1	15 -19	7.7
45 -64	13.9	20 -29	15.0
65 -up	3.6	30 -39	11.9
		40 -49	8.2
		50 -59	5.6
		60 -up	5.3

1/ UN Report on population, 1963.

2/ East Pakistan Nutrition Survey, 1966.

Children up to the age of 14 constitute 38.2 percent of the population in Asia and 46.4 percent in East Pakistan. Since dietary surveys of population groups in various countries provided information available at national and family levels, the distribution of food within the family and nation among age groups is difficult to assess. However, many survey reports indicate that men are nourished more than women and women are better nourished than children. Plasma albumin closely reflects the state of nutrition with regard to the problem. The proportion of deficient and low albumin concentration is higher among growing children than adults of the same sex. This is clearly seen from the percent distribution of plasma albumin levels in East Pakistan Survey (Fig. 1).

Retardation of growth is one of the more obvious signs of protein-calorie malnutrition, and this is very much present among children of Asia. Figure 2 demonstrates the weight curves of American and Thai infants (Valyasevi, Protein Calorie Malnutrition in Thailand, Far East Symposium on Nutrition, Taipeh, 1964). It would be seen that body weight in the first 6 months of

life in both American and Thai infants were found to be similar. After that, weight gain in Thai infants was much slower, with practically no gain from 18 to 24 months of age. Improper feeding is considered to be responsible for the growth failure. Considerable retardation in growth is also evident when East Pakistani children are compared with European children. The differences are minimal at birth and develop between 9 and 24 months, which is the time of weaning. While the relative effect of genetic factors in producing such differences could not be ascertained, the available evidence suggests that nutritional deficiencies, principally protein-calorie, influence the growth rate within the limits of the genetic potential. Thus, delayed growth and lesser adult height and weight may be the result of malnutrition in the critical preschool period.

Kwashiorkor, marasmus, and other symptoms of protein deficiency are prevalent in parts of Asia, notably South India and East Pakistan. In East Pakistan, it shows a seasonal pattern; and around the month of November, over 4 to 5 percent of the children under 5 years of age show up these clinical conditions. Frank kwashiorkor was reported from Bangkok and from hospitals of northern, northeastern, and other regions of Thailand. It has been estimated (Valyasevi) that for every case of kwashiorkor there will be 100 cases of protein malnutrition in the region. Mortality rate of children of 1 to 4 years is perhaps a good index of protein malnutrition in that region. Besides survivors may suffer irreversible ill effects, physical and mental.

Mortality rates of these children are 11 per 1,000 in Thailand, 33 in south India, and 88 for East Pakistan, as compared with 1.1 in the U.S.A.

This is partly due to the effect of diarrheal diseases, measles, and respiratory infections, which precipitate fatal protein malnutrition in children where protein nutritional status is already precarious and whose growth and development are, for this reason, virtually at a standstill (Behar, 1958). Moreover, in protein deficient children, death will occur from infectious diarrheas that would not be serious in well-nourished children or from complications of common respiratory and childhood infections that are rarely fatal when nutrition is adequate. "The frequency of diarrheal disease and severe respiratory infections are so high among preschool children in these countries that they are an insuperable obstacle to adequate nutrition."

One might recall here the study of Gordon with children under 1 year of age (J. E. Gordon and coworkers, Am. J. Med. Sci. 245-346, 1963), in the Punjab where he found an astounding difference in mortality between infants who were breast-fed with some supplementation (120 per thousand) and infants who were not breast-fed (900 per thousand). The findings of INCAP in Guatemala in the three villages--Santa Catarina Barahona, Santa Maria Cauqué, and Santa Cruz Balanya are too well known to be repeated here (Scrimshaw, Second Far East Symposium on Nutrition, 1964). With regard to parasitism,

it is considered that a well-nourished individual is not susceptible to parasitism and may even have fewer parasites under the same environmental conditions (Holmes and Darke, 1959). For a specimen of the Asian scene on the prevalence of diarrhea and respiratory infection, again the findings of East Pakistan Nutrition Survey are shown below:

Disease History of Children Under 5 Years of Age
(East Pakistan)

Diarrhea:	Male, percent	Female, percent
Current	31.8	29.5
Recent	21.3	19.6
Recurrent	28.6	34.2
Respiratory infection:		
Current	38.1	41.8
Recent	23.0	21.2
Recurrent	23.0	21.8
Parasites	52.5	50.7

Protein malnutrition is more often than not attended with vitamin A deficiency resulting in keratomalacia among children of Asia. The problem of vitamin A nutrition is quite a serious problem in Vietnam, Thailand, and East Pakistan. This is illustrated by the prevalence of below "acceptable" serum vitamin A levels in these countries as shown here:

Serum Vitamin A Levels

	Percent prevalence below acceptable
Vietnam	44
Thailand	38
East Pakistan	30

The incidence of xerophthalmia in preschool infants aged 1-5 years is 1.1 percent. This age group of 1 to 5 years represents 16 percent of the total population of East Pakistan. If 50 percent of these deficient children develop xerophthalmia, one gets the figure of 50,000 children who could be blind at any point of time. Since the absorption of vitamin A is impaired in protein deficiency (Arroyane and coworkers), and that mobilization of vitamin A reserve at a critical period may be impaired, it would indicate

that protein malnutrition aggravates vitamin A deficiency. This may be responsible to a corresponding extent for the widespread occurrence of blindness due to vitamin A deficiency in these countries.

The nutrition of expectant and nursing mothers is of great importance. Infants born of malnourished mothers start life with a handicap which may never be completely overcome. The infant may not even survive if the mother's nutrition is inadequate. High incidence of pregnancy wastage, premature birth, and neonatal mortality may well be related to the state of nutrition of the mother. It is considered that about 900 to 950 g. of additional protein are needed for one pregnancy. The nutrition of nursing mothers is also equally important. The average daily secretion of milk is between 850 and 1,200 ml. On the basis of 1.2 g. of protein per 100 ml. of human milk, the protein output in the form of milk is about 15 g. per day. It has been therefore recommended that at least 15 g. of "reference protein" should be available in the daily diet of a nursing mother.

In a survey carried out in Ubol, Thailand, on pregnant and lactating women, the following results were found showing the serious lack of protein in their diet.

Per Caput Per Day 1/

Nutrients	Actual intake	Recommended allowance	
		Pregnant	Lactating
Calories, number	2093	2300	3100
Protein, grams	51	78	93

1/ Source: A. Valyasevi, Second Far East Symposium on Nutrition, 1964.

In other words, in pregnant and lactating women, the protein intake is about 75 and 50 percent, respectively, of the recommended allowances (National Research Council). Serum albumin levels in these two groups of women are considered to be in the deficient range, less than 3.5 g. per 100 ml. during pregnancy and lactation. In the East Pakistan Nutrition Survey, it was found that 45.3 percent of pregnant and lactating women were deficient in plasma albumin ($<$ 3.5 g. percent).

Such being the state of protein nutrition in major parts of Asia, appropriate short- and long-term measures to remedy the situation are of great concern to the Asians and to discerning men everywhere. Just how formidable is the problem may be appreciated from the tables prepared by FAO/UN in respect to food supply available, short- and long-term targets, and the projected growth of population as shown in the following tabulation.

Nutrition Targets for the Far East, Including Mainland China[1]

	Per caput per day		
	Available 1963	Targets 1975	Targets 2000
Calories, number	2,080	2,310	2,400
Total protein, grams	56	68	74
Animal protein, grams	7.6	12.5	20
Overall index of per caput food supply	--	131	170
Overall index of per caput animal food supply	--	163	267

[1] FAO, 1963.

The UN estimate on projected population growth in the Far East, including Mainland China, is shown below[1]:

Year	Population (millions)	Index No. (1960=100)
1975	2062	132
2000	3011	193

[1] UN Provisional Report on World Population Prospects, New York, 1963.

The overall index No. of needs of total and animal food supplies in the Far East, including Mainland China, is as follows:

Target and year	Total food	Animal food
Short-term target (1975)	173	215
Long-term target (2000)	328	515

The condition precedent to the solution of any problem is the recognition of the problem itself with all seriousness. How far that condition is fulfilled in various parts of Asia is a matter of opinion. It seems to me, however, that the predominant feeling is: As long as rice and wheat are available, there is no need to worry.

The obvious solution of the problem is (1) production of proteinous food, (2) prevention of loss and dissipation, and (3) better and more judicious utilization of what is available now and what is produced in the future.

Among the proteinous food, meat, milk and dairy products, poultry, and fish are the most important sources. In Asia, the scope for any spectacular improvement in the production of meat and dairy products does not exist; for the limiting factor here is land, for which men and animals compete. From Table 4 (UNICEF publication ACCY/WP/10, August 6, 1965), it would seem that the annual milk production per caput declined in all countries of Asia except Japan, Taiwan, and possibly Burma.

Table 4.--Annual milk production in Asian countries

Country	Total Milk Production (thousand metric tons)		Annual Per Caput Milk Production (kg. per annum)	
	1948/50	1960/62	1948/50	1960/62
India	19,225	19,718	53.7	45.3
Pakistan	5,817	6,341	77.8	67.1
Japan	306	2,146	3.7	22.8
Burma	218	271	11.8	12.3
Ceylon	100	120	13.0	11.8
Taiwan	1	5	0.2	0.5

Even then, efforts are needed to introduce a better breed of animals which are more efficient converters of feed into food. But here again, the limiting factor is also nitrogenous (proteinous) feed. Compared with the production of meat, such as beef, poultry offers a better promise of increased production. In East Pakistan, where poultry is raised in the kitchen garden, the greatest threat to its becoming a booming cottage industry is a common disease such as Newcastle disease, for which effective vaccine is not available there. Even with vaccine that is available, irrespective of its worth, it does not reach the rural communities where it is needed. Introduction of a potent vaccine and other measures to cut down poultry diseases would greatly help in the increased production of poultry.

The most important potential source of animal protein in Asia is fish which does not compete with man as cattle do for land. Here not only the great oceans of the world, the Indian and the Pacific, and the Arabian and China seas have their long shores, but the land also cradles innumerable fresh water rivers and lakes, which should be able to produce plenty of fish. In 1963, 17.2 million tons of fish were caught, and this was more than half of the total world catch for human consumption. It should be, however, noted that Japan and Mainland China were the two countries which did most in this regard (Table 5).

Table 5.--Fish for human consumption

Location	Average annual per caput production in kg. live weight				
	1938	1948	1958	1960	1963
World	8.34	7.10	9.46	9.95	10.39
Asia	7.61	4.96	8.63	9.27	9.52
Asia (excluding Japan and Mainland China)	7.9	5.9	5.7	5.9	6.3
North America	17.67	17.50	14.06	13.59	13.44

Undoubtedly the other countries of Asia have not harnessed their potentiality in this regard; and there is no reason why they should not be able to do as well as China or Japan has done, once scientific data and the technique together with necessary equipment and capital are available. In a country like East Pakistan, which is studded with innumerable tanks and low-lying areas and rivers, the scope of fresh water fisheries development is enormous. However, its growth is impeded, in my opinion, by the lack of requisite knowledge of pisciculture and by such handicaps as joint ownership of tanks and lagoons. The difficulties of communication and transportation from the place of production to the place of consumption and virtual absence of any facility for storage and preservation are further impediments. Recent advances in the technology of fish products, such as production of fish powder, are expected to stimulate increasing use of fish in these countries.

On considering plant sources for proteins, legumes seem to be the most important. While yielding as many calories per unit weight as cereals, their protein content ranges from 17 to 38 percent, about double that of cereals like rice or wheat and somewhat higher than the values for fish or meat and ten times more than that of tuber. Protein content of some of the more important legumes popular in Asia are quoted in Table 6 along with the values for rice, wheat, and maize.

Apart from being a very rich source of protein, legumes have other advantages. Growing more legumes where the need exists does not present any serious difficulty. Since legumes enrich soil through nitrogen fixation in symbiosis with certain bacteria, this enrichment helps the production of other crops also--and hence, the well-known practice of rotation of crops. Indeed symbiotic fixation may be equivalent to 100 to 200 pounds of nitrogen per acre. Besides, legumes do not pose as much of a problem of preservation as animal protein foods will do.

Table 6.--Protein contents of various foods

Food	Protein, percent	Food	Protein, percent
Rice (*Oryza sativa*)	6.7	Pigeon pea (*Cajanus indicus*)	20.9
Wheat (*Triticum vulgare*)	10.9	Bengal gram (*Cicer arietinum*)	20.1
Maize (*Zea mays*)	9.3	Black gram (*Phaseolus mungo*)	23.9
Kidney bean (*Phaseolus vulgaris*)	22.1	Soybean (*Glycine max*)	38.0
Lentil (*Lens esculentus*)	24.2		
Groundnut (*Arachis hypogea*)	25.6	Khasari dhal (*Lathyrus sativus*)	25.0

The FAO Production Year Book, Vol. 17, 1963, shows the following estimation of production of grain legumes in Asia:

Regional Production in the Far East Including Mainland China

Grain legumes	Thousand metric tons		
	1960/61	1961/62	1962/63
Major grain legumes[1/]	10390	10475	10560
Groundnuts	5710	5930	5890
Soybeans	1290	1290	1190

[1/] Dry beans, dry peas, dry broad beans, chick peas, and lentils.

In the countries of Asia, the bulk of the protein needs must be supplied by legumes. Legumes, often known as poor man's meat, are cheaper. The yield of protein in the form of legumes per unit area of land is about the maximum. This is of great consequence in the densely populated areas of Asia.

As mentioned earlier, the quality of vegetable protein, legume protein in particular, is inferior. Legumes by themselves should not be the sole supplier of protein of growing children, as they are of poor quality compared with animal proteins. The majority of reported PERs for legume proteins are between 0.5 and 1.50 with soybeans coming between 1.5 and 2.5. Most cereal proteins have PERs between 1.0 and 2.0 and meat and egg proteins from 2.5 to 3.5. Legume proteins are poor sources of the sulfur-containing amino acids,

methionine and cystine, and many are also deficient in tryptophan, but they have, in general, high contents of lysine which is the limiting amino acid in cereals. The combination of cereal and legume therefore generates higher protein value as illustrated in the case of maize and cow pea (Table 7).

Table 7.--Relation between combination of maize and cow pea proteins and efficiency ratio[1/]

Percentage of protein from maize	Percentage of protein from cow pea	PER
100	0	1.22
75	25	1.59
50	50	1.84
25	75	1.82
0	100	1.41

[1/] Legumes in Human Nutrition, FAO, No. 19, p. 74, 1964.

Voluminous research has been carried out on the protein values of different combinations of cereals (staple) and legumes in varying proportions always leading to improved values. One must realize, however, vegetable protein mixtures are not as good as animal protein but only nearly so.

Table 8 illustrates the point further.

The effect of legume (pulse) in practical nutrition is vividly illustrated by the findings of the East Pakistan Nutrition Survey shown in Fig. 3. During the months of February to April, October to December, when legume intake is low, plasma protein levels are low and there is the highest incidence of kwashiorkor and marasmus. While during the rest of the year, when pulse intake is high, there is higher level of protein in the plasma and the prevalence of kwashiorkor is also low. The most commonly consumed legumes in the Indian subcontinent are: Bengal gram (Cicer arietinum), green gram (Phaseolus aureus), black gram (Phaseolus mungo), red gram (Cajanas cajan), dried peas (Pisum sativum), lentils (Lens esculenta), and khasari dhal (Lathyrus sativa). In areas like Madras and Kerala, 26 g. per consumption unit per day is a typical figure, and intakes in the Panjab and Behar are in excess of 80 g. In East Pakistan, the per person per day consumption is 28.0 g. (East Pakistan Nutrition Survey, 1966).

The comparatively higher figure for India is due to the fact that the Hindus, in general, are vegetarians. In Burma, the daily per caput consumption is about 14 g. In Thailand, the consumption of legumes appears to be small.

Table 8.--Protein values (NDpCals %) of mixtures of various staples with legumes and other foods, the mixtures providing 2,200 calories1/

Staple alone		Cassava flour	Rice	Sorghum	Wheat	Maize	1/2 Maize 1/2 Cassava
		Net Dietary Protein Calories Percent (NDpCals %)					
		1	4.9	4.6	5.7	4.8	3.4
Food substituted for proportion of staple	Quantity substituted, grams						
Legumes in general	30	1.5	6.2	6.1	7.0	6.3	4.2
Legumes in general	60	1.9	6.7	6.6	8.3	6.5	4.5
Legumes in general	90	2.3	6.5	6.8	8.3	6.6	4.8
Soybean	30	2.1	6.5	6.7	7.2	6.7	5.0
Soybean	60	3.9	7.4	7.4	9.0	7.1	5.8
Soybean	90	4.9	8.0	8.0	9.5	8.0	6.5
Groundnut	30	1.4	5.5	5.1	6.2	5.1	4.2
Groundnut	60	1.8	5.9	5.6	6.5	5.9	4.4
Groundnut	90	2.2	6.2	6.0	7.0	6.1	4.4
Low fat groundnut flour	60	3.1	7.1	7.0	7.9	7.0	5.4
Skim milk powder	30	2.5	7.1	7.8	8.0	7.0	5.2
Skim milk powder	60	4.1	7.9	7.9	9.4	7.5	6.1
Fish meal	30	3.7	7.7	7.5	9.2	7.4	5.8
Fish meal	60	5.9	8.8	8.8	10.1	8.7	7.3
Legumes in general	45	2.2	6.8	7.0	8.8	6.9	4.8
Skim milk powder	15						
Soybean	45	4.0	7.5	7.7	9.2	7.4	5.7
Skim milk powder	15						
Legumes in general	45	3.0	7.0	7.1	9.0	7.0	5.4
Fish meal	15						
Low fat groundnut flour	30	4.1	7.2	6.8	7.4	7.0	6.2
Low fat sesame flour	30						

1/ Legumes in Human Nutrition, FAO, No. 19, p. 75, 1964.

The per caput supply of mung beans, soybeans, and groundnuts are 4.1, 2.4, and 15.5 g., respectively; but most of them are for the commercial production of oil. In Malaya, the Malaya people do not use much legumes, but those of Indian origin use about 27 g. per day. The most common is the green gram. For Indonesia, recent data are not available. The per caput supply of soybeans and groundnuts in 1940 was reported to be 15 g. and 8 g., respectively. Many other legumes are also consumed, and the consumption varies from 30 to 50 g. to 4 to 5 g. In addition to soybeans and groundnuts, the most popular legume is green gram. In Japan, the soybean is the most important legume, which is produced in the order of millions of tons and supplies about 12 percent of the total protein, while other legumes (groundnuts, red beans, and kidney beans) supply about 1 to 2 percent. Korea and Taiwan will probably resemble Japan in the use of legumes. In Mainland China, the home of the soybean, it must have remained the most important legume. It is estimated legume supply there is about 42 g. per head daily to which soybeans contribute 18 g. Of all the legumes, perhaps soybeans and peanuts deserve special consideration because of their better yield per acre (Table 9), and high biological value, and high protein content.

Table 9.--Yield of protein of different grain legumes[1/]

Crop region	Kilograms per hectare			
	Latin America	Near East	Far East	Africa
Soybeans	327.4	315.4	269.8	178.6
Groundnuts	225.6	172.9	160.0	158.3
Dry beans	125.9	274.0	68.5	128.8
Dry peas	155.2	225.0	117.0	171.0
Dry broad beans	--	327.6	311.2	117.8
Chick peas	180.9	195.0	98.5	116.5
Lentils	171.8	246.8	96.8	137.9

[1/] Nutrition document R.I/Ad 25, PAG (WHO/FAO/UNICEF) August 1966.

The soybean, because of its high-protein content and high biological value, would appear to be the best source of plant protein. In Mainland China, Indonesia, and Japan it is the most preeminent legume. But to the rest of Asia, the soybean seems to have failed to establish itself as a major legume. Among the shortcomings are (1) disagreeable taste (bitter), (2) longer time required for its cooking in countries where economy has to be made on fuel, (3) presence of a considerable amount of indigestible carbohydrates such as galactans, and (4) presence of such toxic substances as trypsin inhibitors. In the soy countries of Asia, the soybean is to a large extent used as fermented products. Soy sauce and soybean paste

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(Aspergillus oryzae), tempeh (Rhizopus oryzae), and natto (Bacillus subtilis) are part of the cultures of these countries. It is difficult to implant foreign culture over others. Undoubtedly, further research will have to be undertaken to remove the shortcomings of soybeans mentioned above. It is known that adding sodium bicarbonate to the soaking and cooking water for dry beans reduces the time needed for cooking by about one-third. In my own country, housewives use papaya latex or green papaya mash to partly digest tough meat, which would have otherwise taken a much longer time to cook. It is conceivable that simple and unsophisticated methods could be discovered to make soybeans acceptable to larger numbers of protein-hungry people of Asia and elsewhere. Short of these limitations soybeans remain the best potential source of protein of the plant world.

The economy of both soybeans and groundnuts is mainly based on their oil content, and the press cakes are mostly used as fertilizers or animal feed. The press cake from peanuts retains a considerable residue of oil, and this is removed in order to make it suitable for human consumption. Refined groundnut flour in combination with cereals and/or skim milk powder, promises to be of great value in the nutrition of infants. The Indian Multipurpose Food which is a blend (75:25) of low-fat peanut flour and Bengal gram fortified with vitamins and supplemented with a small amount (80:20) of milk powder was found to be useful in the treatment of kwashiorkor (Sreenivasan, in Progress in Meeting Protein Needs of Infants and Preschool Children). However, the discovery that groundnuts become contaminated with Aspergillus flavus, a common fungus that produces a hepato-toxin (aflatoxin) has seriously threatened the prospect of increasing popularity of groundnuts. This is especially true in Asia where poor storage facilities and climatic conditions are highly conducive to the growth of the fungus.

The crying need of protein in Asia is for the children. As milk and milk products are either not available or too expensive for those who need the protein, substitutes principally based on legumes like soybeans and other legumes are the only answer. The efforts of such organizations as UNICEF/WHO in the formulation of such products in many parts of the world cannot be over appreciated. Further research and efforts to cover more countries of Asia are needed. To protect the protein deficient in Asia, much more emphasis on nutrition education among the general public, planners in the Government, and the administrators is essential.

Agriculture in countries like Pakistan is cereal-based. One calculates the produce in terms of kilograms of grains, not in terms of nutrients. Most of the agricultural researches in these countries are directed to produce more rice. Research is to be undertaken on the effect of cooking procedures peculiar to a country on the nutritive value of its food. This is especially so when protein foods are known to suffer in their nutritional value by overheating or overcooking. One wonders about the effects of other ingredients in the Asian recipes on the biological value of the proteins. It is common knowledge that in the Asian countries with protein deficiency, severe

deficiencies of riboflavin and vitamin A coexist. It is likely that the deficiency of riboflavin, which enters into the key enzyme reactions of the body, may impair the full utilization of the ingested protein. Pioneering researches that are being carried out in the International Rice Research Institute (IRRI), Los Banos, the Philippines, to evolve rice rich in protein may change the course of human history. The IRRI variety of rice is already giving double the usual yield per acre in East Pakistan. In West Pakistan, the history of Maxipak wheat may be equally exciting. We are at a point of time in the history of man on this earth when we could speculate in manipulating deoxyribonucleic acid (DNA) of even man, hence the prospect of incorporating qualities of meat into that of rice may not stagger anybody's imagination.

To summarize, there is widespread protein deficiency in all countries of Asia, the worst affected being the children.

More protein and their judicious uses are the need of the day. More efforts are to be made to produce more fish, poultry, and legumes. Among legumes, soybeans would appear to be the best, provided such drawbacks as bitter taste, difficulty in cooking, and the presence of growth inhibitors could be eliminated. Further research is needed.

Nutrition education at all levels is essential for the improved nutrition of the people of Asia. The services already being rendered by UNICEF through the introduction of protein-rich food for children and applied nutrition programs should be extended to reach as many countries in Asia as feasible.

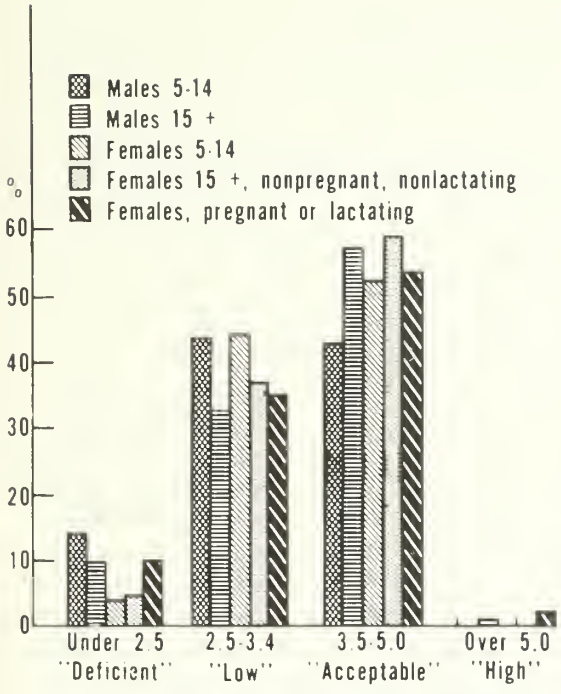


Figure 1. Percent Distribution of Plasma Albumin Levels

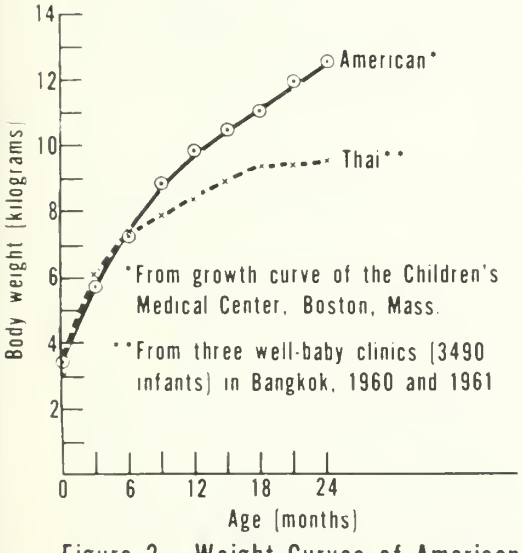
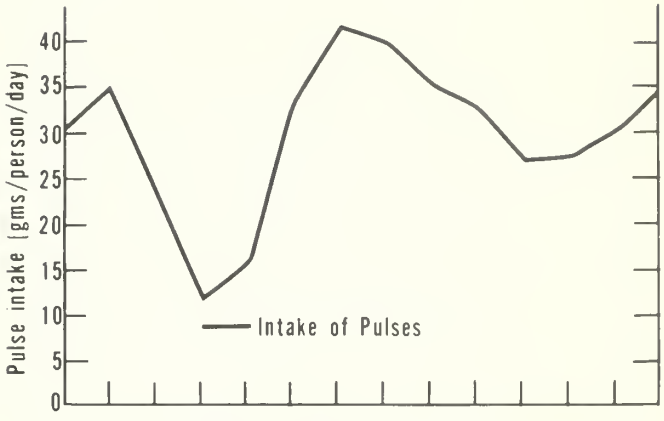


Figure 2. Weight Curves of American and Thai Infants



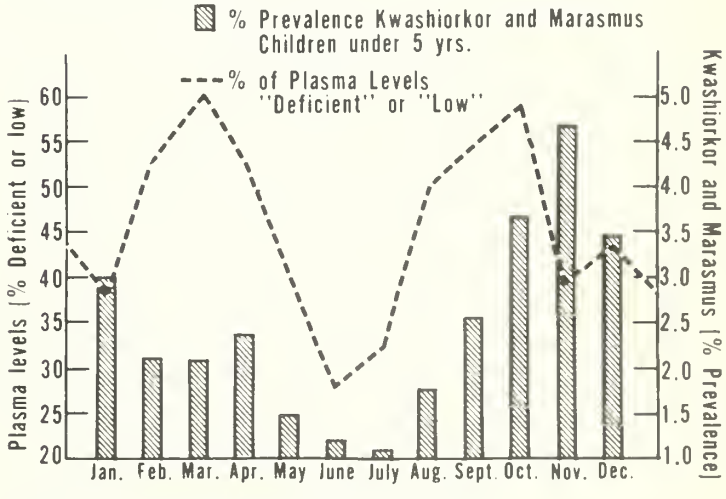


Figure 3. Seasonal Protein Correlations

SESSION II: NUTRITIONAL AND CHEMICAL STUDIES

John C. Cowan, Presiding
Chief, Oilseed Crops Laboratory
Northern Utilization Research and Development Division

DIETARY PROTEIN QUALITY IN MALNOURISHED INFANTS: SOY PROTEINS

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In the development of foods for the prevention of malnutrition, we often lose sight of the fact that there are two fairly distinct goals to be met. Most widely recognized is the need for high-protein supplements to the poor diets of preschool children, school children, pregnant and lactating women, and other vulnerable groups. Although the quality of the protein in these foods is important, the relatively high concentration in which they can be presented, the fact that they are not meant to be the only food, and the relatively mature and efficient digestive systems of the individuals who are meant to consume them, allow considerable leeway in their formulation and evaluation. If the proteins in question have a score of 70 or better, if the PER in rats is in the vicinity of 2.0, if they can maintain adult humans in nitrogen balance, and if they will support "normal" growth in children, they are almost certain to prove satisfactory as supplements to the diets of vulnerable groups.

The second goal, and in our opinion the most important, is the need for complete foods which can replace human breast milk as the only food for the millions of infants who are weaned before 6 to 8 months of life. Despite many centuries of experience with cow's milk as such a substitute, we are still having to make modifications in this product to keep up with newer knowledge and make it adequate for nearly all infants. Success in the development of new and less expensive substitutes will not come easily. It is pertinent to the purpose of this meeting that the only other substitute which has met with wide success has been soy milk. Lest we think that this is simple, we must point out that in the soy milk available in this country wide differences in protein quality exist, and that even with the best we not infrequently encounter problems of adequacy in special circumstances.

The full-term human infant is born with a generous store of all known nutrients and can withstand deprivation for variable periods of time. Starvation can be survived for many days, even by the premature. Imbalanced

nutrition, however, is a very different problem. Inadequate provision of water in the face of a heavy solute load leads to dehydration and hyperosmolarity in a few days. Inadequate provisions of carbohydrate lead to hypoglycemia and ketosis, insufficient intakes of ascorbic acid result in impaired tyrosine metabolism, and shortage of pyridoxine in convulsions and impaired tryptophan metabolism. A low calcium phosphate ratio in the diet leads to poor calcium absorption and hypocalcemia, inadequate intakes of vitamins D and A can be tolerated for a few weeks. Recently, it has been demonstrated that a low intake of vitamin E, particularly if accompanied by a high one of polyunsaturated fatty acids, can lead in a very short time to serious difficulty. By contrast, however, poor intakes of iron and copper can be tolerated for many months by the full-term infant, though not as well by the premature.

In defining the adequacy of protein quality for the infant we must take into account a number of important variables. If we attempt to overcome deficiencies in quality by a more generous provision of protein, we immediately run into the problem of the solute load, at an age when the renal capacity is already being taxed by the higher protein requirement for rapid growth and by the much higher insensible water losses per unit of weight or surface area. When we reach 15 percent of protein calories, we have more than doubled the amount in human breast milk. In the digestion of protein by the adult or older child, the endogenous contribution of amino acids to the intestinal content is at least 50 percent of the total, making it possible to tolerate and utilize imbalanced dietary protein for relatively long periods of time. In the young infant, and notoriously so in the malnourished one, dietary amino acids represent a much higher proportion of the total, making their individual concentrations and the balance between them of much more critical importance. The rapid growth rate of the first year of life makes for important differences in the proportion of amino acids used for this purpose as against those required for maintenance, and accounts for at least some of the differences in amino acid requirements at different ages. The vulnerability of the infant to infection and the frequency of such insults results in frequent periods of depletion of "labile" proteins and requires that dietary protein be adequate for their prompt repletion. Finally, at least one amino acid, histidine, is essential for the infant but not for the adult.

With these considerations in mind, we have developed an approach to the evaluation of dietary protein quality which is possibly hypercritical but which has provided very suggestive information. In convalescent malnourished infants and children, we compare rates of weight gain, apparent nitrogen absorption and retention, and serum protein levels with those obtained with modified cow's milk at isocaloric, isonitrogenous levels. We then give the same product as the only source of protein for periods of 4 to 12 months, and if the results are satisfactory, we use it as the only source of protein in the initial treatment of malnourished infants and in the diet of very

young infants. The ability of dietary proteins to initiate recovery in kwashiorkor gives us a measure of their ability to replete labile proteins, and their ability to support nitrogen retention and growth in the marasmic or very young infant gives us a measure of their ability to support growth.

We have evaluated a variety of soy products in this fashion and have found important differences, which must in part be attributed to the effect of processing. Beginning with a well-known soy milk, which gives results very near to those of a modified cow's milk, we have studied a soy protein isolate, a full-fat soy flour, a corn-soy mixture enriched with methionine, a cottonseed-soy mixture, a cassava-soy mixture, a chick-pea-soy mixture, and most recently a soy milk made from a soy protein isolate.

FORMULATED SOY BEVERAGES FOR INFANTS AND PRESCHOOL CHILDREN

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Introduction

The title assigned to me allows considerable latitude in choosing the specific points to be covered in my talk. I shall confine myself to reporting the effects of processing on the chemical composition of soy milk and also limit myself to those constituents of soy milk that are related to wholesomeness, nutritive value, and flavor. It is obvious that factors influencing wholesomeness and nutritive value are especially important in beverages to be used by infants and preschool children.

This presentation is in the nature of a progress report. I am taking the liberty of reporting on some work that is not yet complete and of speculating about some points that have not yet been tested.

The experimental results that I shall describe have been obtained by a group of scientists working as a team at the New York State Agricultural Experiment Station.

Previous Work

In prior publications, it has been reported that the classical method of making soy milk involves a separation of soybean fractions that differ considerably in composition and nutritive value. The beans are first soaked, and a water-soluble extract is then prepared by wet grinding and filtering. The fractions that are removed are the hulls, the soak water, and the insoluble residue (Hand and coworkers, 1964). Table 1 shows the gross composition of these edible fractions. Figure 1 shows the distribution of solids and protein in the various fractions.

Some rather surprising results were obtained in growth studies with weanling rats. The protein efficiency ratio (PER) of soy milk was slightly less than that of the original soybeans, and PER of the insoluble residue was definitely higher than any of the other fractions. Although the observed differences have not yet been quantitatively explained, it is clear that the insoluble and indigestible carbohydrate in the residue did not diminish the growth rate in weanling rats. The PER values for soak water proteins were not reported because the rats did not grow or survive when fed this fraction.

Table 2 shows the differences in protein quality of the various fractions as measured by the growth of weanling rats (Hackler and coworkers, 1963).

Table 1.--Composition of soy milk fractions (figures in percent on dry basis)

Fraction	Max. possible yield	Crude protein	Free fat (ether ext.)	Bound fat	Fiber	Moisture	Other ingredients
Dehulled whole soybeans	90	41.9	21.2	7.1	1.1	2.9	25.8
Dehulled soaked whole soybeans	80	45.0	23.3	7.6	1.9	2.9	19.3
Water extract of soaked soybeans	65	49.4	13.1	15.6	0.1	3.2	18.6
Residue from water extract (minus hulls)	24	21.2	9.7	6.3	9.6	4.9	48.3
Acid curd	49	57.5	30.4	7.4	0.2	2.3	2.2

Table 2.--A summary of the effect of soybean fractions upon growth of weanling rats when diets supplied 10 percent protein

Item	Diet designation by protein supplement					
	Casein	Dehulled soybeans	Residue	Soy milk	Curd	Whey
Average daily gain, grams	4.18	3.95	4.90	2.63	2.69	1.37
Average feed intake, grams	14.34	15.59	18.22	12.70	12.20	7.08
Protein efficiency ratio (PER)	2.86	2.51	2.71	2.11	2.20	1.93

Table 3.--Percent composition of a 24-hour soak water from dehulled beans[1/]

	Grams/100 g. dry solids	Percentage composition
Total nitrogen	3.73	
Nonprotein nitrogen[2/]	1.89	
Crude protein		23.3
Total fat		2.8
Fiber		0.8
Sucrose[3/]	4.47	
Raffinose[3/]	1.50	
Stachyose[3/]	3.48	
Total carbohydrate (by difference)		73.1
		100.0

1/ Soak water temperature, 2° C.

2/ Nonprotein nitrogen method by Becker and coworkers (1940).

3/ Sugars by method of Shallenberger (1957).

Wet versus dry processing

A wide range of processes are available for making soy beverages. The choice of the process is important because it will involve differences in cost, acceptability, wholesomeness, and nutritive value. In the simplest terms, the first choice is between a dry process and a wet process. If a wet process is used, there is a further choice of whether to soak the beans before extracting with water. Finally, the extraction can be carried out with either hot or cold water.

Compositional differences between dry-process and wet-process soy milk are shown in Table 1. In the dry process, the soy milk has the same composition as dehulled whole soybeans, which differs from the water extract in having a lower protein and a higher carbohydrate content. Differences in chemical composition, nutritive value, and flavor are relatively slight; but the differences in physical properties are very pronounced.

The dry process for making soy milk involves treatment with steam to inactivate the antitrypsin, followed by drying and grinding. The dry powder can be suspended in water with a high-speed blendor or homogenizer to give a milk with much the same appearance as the wet-process soy milk. The particles are, however, much coarser and will not pass through a milk filter. To produce a stable suspension with 8 percent solids a stabilizing agent must be added.

To soak or not to soak

Soaking removes between 1.5 and 15 percent of the soybean solids, depending on the conditions. Table 3 shows the composition of soak water after 24 hours of soaking at 2° C. High values were observed for carbohydrate and nonprotein nitrogen. The carbohydrate content of soak water solids is about three times that of the original dehulled beans and the nonprotein nitrogen is about 10 times as high as the original beans. Due to the low yield of soak water solids, the amount of carbohydrate that is removed is a small fraction of the total.

Analyses were made to determine if soaking reduced the amount of raffinose and stachyose in soybeans. A rather surprising result was obtained: that the oligosaccharides decreased in the soaked beans but that only a small proportion of the decrease could be accounted for in the soak water. Figure 2 shows the distribution of the original oligosaccharides among the various soy fractions after a 24-hour soak. There was a 60 percent decrease in stachyose but only 5 percent diffused into the soak water.

It would appear that during soaking a number of biochemical changes occur that might be related to the transformations during the early stages of germination. References in the literature have reported the disappearance of the oligosaccharides of soybeans during germination (Pazur and coworkers, 1962). There are, therefore, two possible ways in which soaking of soybeans can bring about changes in composition: (a) By leaching of solutes, and

(b) by *in situ* biochemical changes. The leaching effect appears to be accentuated by soaking dehulled beans at elevated temperatures for short periods of time. Figure 3 shows an experiment in which soybean cotyledons were soaked for 3 hours at temperatures ranging from 25 to 65° C. The milks made from these soaked beans were analyzed for carbohydrate, lipid, and protein. The carbohydrate content of the milk fell from 15 percent to 7 percent; the lipid content increased from 32 to 35 percent, and the crude protein content rose from 53 to 58 percent. The yield of soy milk solids dropped from 63 to 54 percent.

If biochemical changes occur and if these are similar to the transformations during germination, we would expect an increase in free amino acids at the expense of the protein and some of the storage fat should be converted with carbohydrate. Preliminary analyses, shown in Table 4, indicate that these changes do occur during soaking at 2° C. for periods of time ranging from 24 to 72 hours.

Table 4.--Effects of soaking dehulled soybeans on content of protein, fat, and carbohydrate[1/]

Hours	True protein grams	Nonprotein nitrogen grams	Total fat grams	Carbohydrate grams
24	38.8	0.284	23.5	24.4
72	34.8	0.856	18.5	34.2

[1/] Figures are totals for dehulled beans plus soak water in gram yield from 100 grams of dry beans. Soak temperature 2° C.

In summary, the effects of soaking are complex. It is more than likely that undesirable or unwholesome substances are removed by soaking. Certainly the soak water has a disagreeable flavor. The soak water will not support growth of weanling rats, although its amino acid content is adequate. More research is needed.

Hot versus cold extraction

In the wet process for making soy milk, the lipids are brought into contact with lipoxidase in the presence of oxygen and a rapid formation of peroxides ensues (Mattick and coworkers, in press). The odor of rancid fat can be detected immediately. The development of rancidity can be

prevented in a number of ways of which the simplest is to extract at a temperature high enough to prevent the action of lipoxidase. The trick is to extract the milk before the heat treatment makes the protein insoluble (Wilkens and coworkers, in press).

The off-flavors due to rancidity can be measured with gas chromatography as shown in Fig. 4. Since these volatile off-flavors can be removed by evaporation, the question can be raised as to whether it is necessary to prevent their formation initially. We were interested in determining the extent of oxidation of the fat during the processing of soy milk. Figure 5 shows the course of the reaction as determined by the increase in optical density of the fat at 232.4 mμ. It can be seen that the reaction stops after 5 minutes. The reason for the stoppage in the oxidation is not clear since calculations show that only 40 percent of the polyunsaturated fatty acids are oxidized in the 5-minute period.

In order to confirm the conclusions reached from optical density measurements, comparisons have been made of the fatty acid composition of the fat after cold extraction and hot extraction. The proportion of polyunsaturated fatty acids is higher in the soy milk after hot grinding. After correcting for the higher yield of methyl esters obtained from the cold-extracted soy milk, there was a calculated loss of 40 percent of the polyunsaturated fats during the cold-extraction process.

In Fig. 6 are shown the peak areas for the methyl esters of the five principal fatty acids in soybean oil. For some unexplained reason, the esterification was more complete in the fat from the cold-extracted soy milk. On the assumption that there was no oxidation of the saturated fatty acids, the peak areas for the unsaturated fatty acids have been corrected to show the initial proportion of unsaturated fatty acids. The differences between the corrected and uncorrected peak areas is a measure of the amount of fat oxidized.

It seems clear that substantial fractions of the linoleic and linolenic acids are oxidized during the processing of soy milk by the cold-extraction method. During the subsequent heating of the milk, the peroxides may react with the cystine in the protein to cause an appreciable reduction in biological value. We have not yet shown that this occurs. There is a report in the literature that the autooxidized ethyl esters of highly unsaturated fatty acids will react with cystine to produce cysteic acid (Matsuo, 1957).

Conclusion

Any one of a number of processes is suitable for making soy milk. Adequate technology is presently available for extending the use of soy milk to countries where dietary protein is inadequate. However, further research

is needed for process and product development. It is especially important in the case of a beverage for infant use to determine if the prevention of fat oxidation and the removal of nonnutrients by soaking increases the wholesomeness of the product. Decisions regarding modifications in the quality of the product should be based on consumer acceptance studies made in the country where the product is to be marketed.

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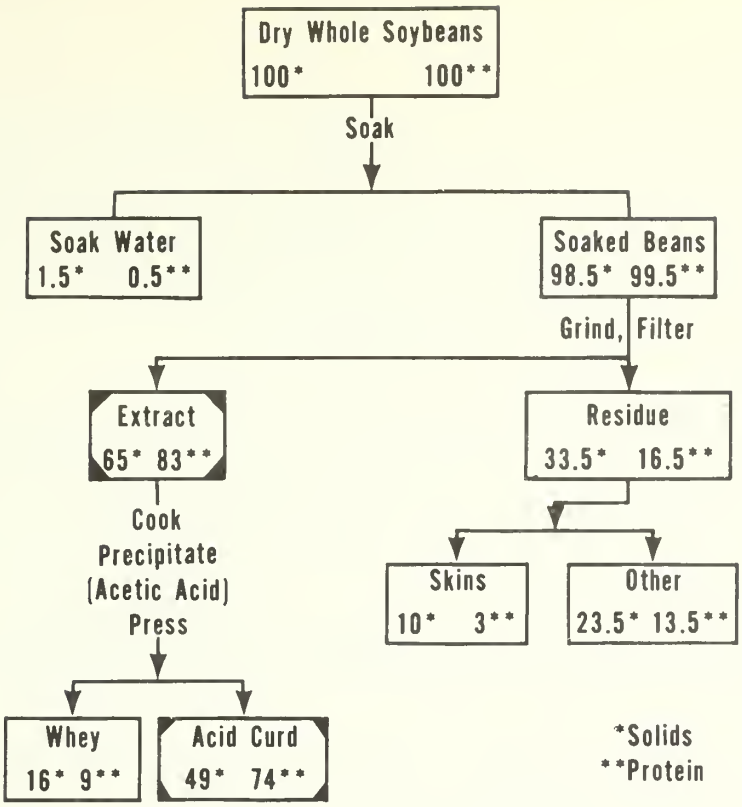

Figure 1. Distribution of Solids and Protein in Fractions from Soaked Soybeans

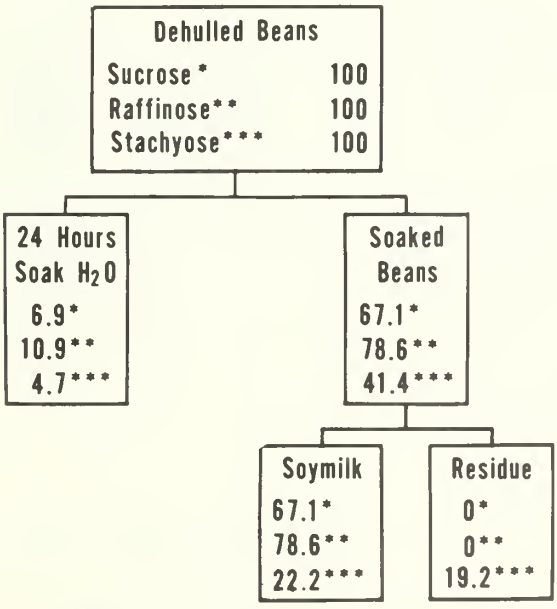

Figure 2. Distribution of Sugars in Production of Soymilk. Figures show percent of sugars in each fraction. Soak water temperature, 2°C.

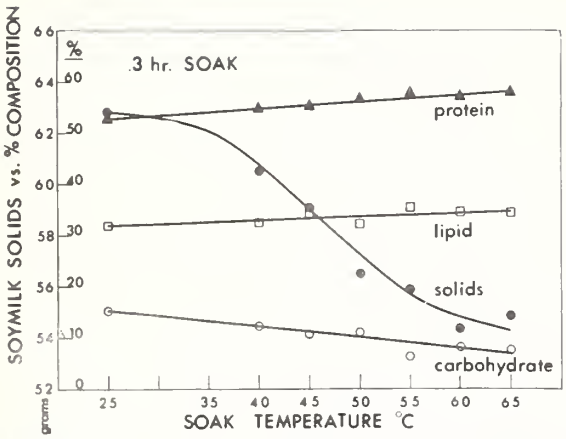

Figure 3. Effect of soaking soybeans on the composition of soymilk.

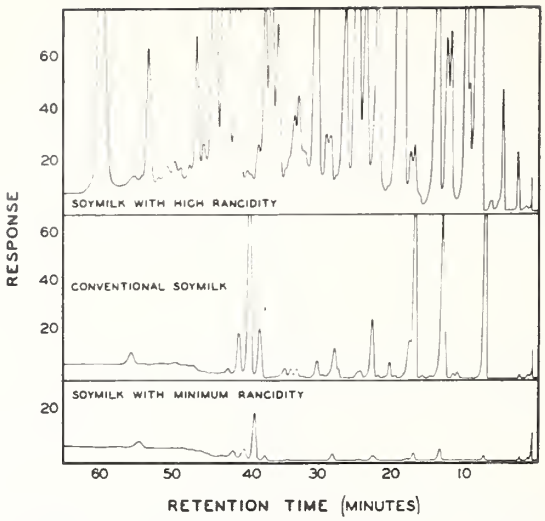

Figure 4. Volatiles in soymilks of varying degrees of rancidity

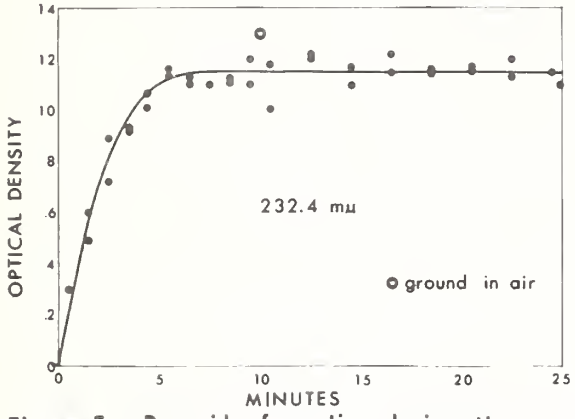

Figure 5. Peroxide formation during the wet Grinding of soybeans.

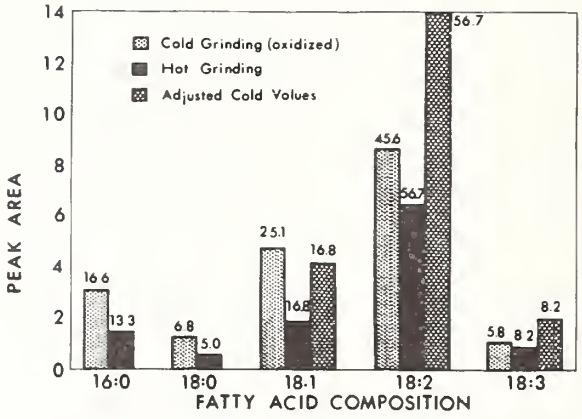

Figure 6. Effect of grinding temperature on the fatty acid composition of soymilk. (Figures show grams of individual fatty acids per 100 grams of fat)

SOYBEAN PROTEIN IN MIXED FOODS

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Washington, D.C.

The use of soybeans to help combat malnutrition in the world well deserves the attention it is receiving here today. It is appropriate that specialists in production, processing, food formulation, nutrition, and medicine are all providing expertise in efforts to realize the full potential of the various forms of this product.

I am considering that the term "mixed foods" in the title of this talk refers to common items in the indigenous diet--items such as tortillas, chapatties, and cereal bases, with or without sauces, items that are consumed with reasonable regularity even though the amounts consumed may be insufficient to sustain adequate nutrition. Thus, mixed foods are differentiated from infant formulas, from special formulations and supplements designed to supply a relatively concentrated source of nutrients to boost the nutritive value of the indigenous diet. Mixed foods are usually consumed by all ages of the population except perhaps by the very young infant. The form of the mixed foods may be altered when they are given to the weanling. The foods may be softened and digestion begun by the mother chewing it before giving to the child, or the food may be diluted or cooked into a gruel. Often the dilution is so great that the child cannot survive on the low calorie-nutrient density of such a gruel.

Whatever the quality of the foods or food derivatives that are used to boost the nutritive content of indigenous foods, certain basic nutritional considerations must prevail. The problem we are trying to solve today is usually referred to as "calorie-protein malnutrition." We recognize that energy alone, or empty calories, or protein per se, will not correct the situation completely because the malnutrition that exists in the world today is multi-nutrient. We use the term "calorie-protein malnutrition" however, because when these two essentials are supplied by suitable combinations of foods, the deficiency conditions grouped under this umbrella term are alleviated.

It is most important that a group with the competencies represented here view the problem of calorie-protein malnutrition in its broadest aspects rather than through a knothole focused on one phase or on one kind of product. Such a view requires awareness of the following points:

1. The priority demand of a living organism is for energy--expressed in the measuring unit of calories. However, empty calories, those combustion units unaccompanied by nutrients, have severe limitations; they do not go

far in maintaining life. Protein is an energy source comparable in calorie yield to carbohydrate. In the absence of sufficient energy from other sources, protein will be used. This means that its nitrogen components will not be available for tissue building and maintenance.

2. The distinctive value of protein lies in its nitrogen component. This is not nitrogen in the free form, but nitrogen incorporated into specific patterns of amino acids. Conventionally, amino acids are classified into "essential" and "nonessential" depending upon whether they must be supplied in the diet already formed or whether they can be synthesized by the body. Only plants can make certain of the amino acids that we need for life. Because no animal body can make them, these amino acids are called "essential"--meaning that they must be supplied preformed in the diet. We are dependent directly or indirectly through use of other animal tissue on some plants for each molecule of these dietary essential amino acids. (Certain microorganisms can form essential amino acids, but their direct usefulness as contributors to the human food supply is not great at this time.)

The amino acids referred to as "nonessential" are those which need not be supplied by the diet because the body can synthesize them from the carbon, hydrogen, oxygen, and nitrogen components in the diet. This classification is not completely accurate because there are circumstances when certain of the so-called nonessential amino acids cannot be synthesized in the quantity or at the rate needed by the body.

The terminology "essential" and "nonessential" is useful when referring to foods but it is misleading when referring to physiological requirement. Both groups of amino acids are essential. The importance of the non-essential ones is equal to that of the essential ones in building and maintaining protein tissue. For instance, if the so-called nonessential amino acids are not present when needed, the essential ones must be broken down and the molecules rearranged to form the nonessential ones.

Determining the optimal proportions in which to supply the body with dietary essential amino acids and with dietary sources of those that can be synthesized is an area that urgently needs further research. For instance, there is evidence that top quality egg protein does not support growth as well when it is fed as the sole source of protein as when it is diluted to some degree with other sources of nitrogen. Similar results have been obtained for milk and casein. In egg protein, the ratio of essential to nonessential amino acids is approximately 1. The implication is that a ratio of 1 is too concentrated for optimal utilization. The ratio in soy protein is about 0.8.

Another frequent misinterpretation of terms similar to that of "essential" and "nonessential" occurs with the term, "limiting amino acid." The essential amino acid showing the lowest percentage in comparison with the

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amino acids contained in the same quantity of another protein selected as a standard is referred to as the limiting amino acid. (This percentage is called the chemical score.) Egg protein is often used as the standard for comparison, but this practice urgently needs reevaluation. Human requirements for the essential amino acids have been used also as a standard.

Soy protein contains from 60 to 105 percent as much of the different essential amino acids as does an equal amount of egg protein. The lowest figure, 60 percent, refers to the sulfur-containing amino acids, methionine plus cystine. Thus the limiting amino acid in soy protein is methionine plus cystine. Too often the term "limiting" is used synonymously with "deficient" without reference to whether the standard is another protein or whether it is the physiological requirement for that amino acid. In comparison with egg, soy protein is "deficient" in methionine-cystine. However, as little as 1 ounce of soy protein will supply the entire methionine-cystine requirement of an adult (although not the requirement for total protein).

3. Meeting protein needs also involves a time factor. All of the amino acids needed for building a tissue protein or a protein constituent of the body must be present simultaneously for the synthesis of that protein portion of the body. Apparently the synthesizing mechanism for each protein operates on an all or none principle. If all the amino acids needed to build a complete protein are not present at the same time and in sufficient amounts, the protein will not be built at all. The time factor becomes more critical as the intake of protein and calories is reduced from optimal to minimal levels. This has implications when considering whether to give a concentrated source of protein in one daily supplement or whether to distribute the protein supplement in the indigenous foods consumed regularly over a longer time span.

4. The measure known as Protein Efficiency Ratio (PER) does not give adequate or accurate evaluation of foods intended for human consumption. During the almost 50 years it has been in use, it has been refined, standardized, and polished in various ways. It seems to have been a good tool for specialists interested in rations that would produce rapid gains in animals for a competitive market--for such purposes, the faster the growth, the better the diet.

PER is not a complete enough measure of the value of foods for people. As now measured, a standard PER involves a 2 to 4 week restricted paired feeding test with a protein level of about 10 percent in a standard dietary pattern of highly available carbohydrate and an ideal fat and assortment of minerals and vitamins. The test is conducted under optimal environmental conditions. Any deviation from a rigid standardized procedure gives inconsistent results for the reference protein (usually casein) as well as for the series of products being tested. Studies made over longer than the

standard 2-or 4-week feeding test indicate that PER values may change significantly during subsequent weeks of feeding. Initial high values may be reduced, perhaps attributable to an unfavorably high ratio of dietary essential to nonessential amino acids. Conversely, an initial low value may be increased.

A PER value is based on gain in weight, and this does not necessarily indicate normal growth or sound development. Used alone, PER does not measure the value of a food for protein synthesis, for adult maintenance, for repleting undernourished and convalescing bodies, for human lactation, or for generating immunological defenses against infections and food or environmental toxins.

For human nutrition, evaluation of a protein must include more than PER values, just as more than iodine value is needed to indicate the composition of a fat, and more than pH is necessary to define the acid base components of a solution. PER ratings cannot be considered applicable to human diets, self-selected or obtained hit-or-miss by a free living population either in a land of plenty or a land of famine. Just as the PER is not enough for evaluating protein for human diets, so does our knowledge of amino acid requirements leave much to be desired. The quantitative values available to us have been obtained under rigidly controlled conditions, on semi-synthetic diets, and with individual amino acids supplied in chemically purified form. The results obtained under such conditions are helpful, but we must recognize their limitations as guidelines for building diets from foods and the food-bound nutrients they contain.

5. The protein content of some foods of plant origin can be overestimated by frequent practice of using the factor 6.25 to convert total nitrogen to protein content. This is true for soybeans.

The use of the factor 6.25 began because some of the first proteins analyzed contained 16 percent nitrogen (100 ÷ 16 = 6.25). This falsely assumed that all nitrogen present in food--that is, total nitrogen--was potentially protein nitrogen. It did not take into account the presence of small amounts of other nitrogenous compounds such as choline, nitrates, nitrites, purine bases, and nitrogen-containing vitamins. Another false assumption in using the factor 6.25 is that every kind of protein in food contains 16 percent nitrogen. However, the nitrogen content of the principal protein in food may vary from a low of 13.4 percent for an alcohol-alkali soluble protein in avocado to a high of 19.3 percent for amadin in almonds.

D. B. Jones and his associates in USDA derived a series of conversion factors for foods and feeds based upon the nitrogen content of protein isolates, but also taking into consideration the various nitrogenous compounds and the nitrogen content of the chief protein or proteins present

in the food. Later the factors were substantiated by amino acid analyses. Use of these factors give the protein content of a food more accurately than does the indiscriminate use of the factor 6.25. The protein content of soybeans is more accurately represented by use of 5.71 as a factor than by 6.25.

In view of these aspects of meeting protein needs, how can soy protein be used most effectively in the world nutrition arena? Adding soy protein to mixed or indigenous foods can, indeed, significantly improve the quantity and quality of the protein available from the food items that are the chief sources of energy.

Such a metered supply of high-quality protein from a food source in the presence of energy and nutrients from even limited amounts of indigenous foods can combat protein malnutrition more successfully than larger amounts of protein given intermittently, than isolated proteins that have been nutritionally damaged in processing, or than purified amino acids separated as they are from other essential nutrients.

To accomplish this, I suggest the necessity and urgency for knowing as much as possible about the indigenous diets in which soy is to be used. This includes knowing not only what foods are available but how they are used, combinations in which they are prepared and eaten, methods of preparation, eating patterns and other mores that surround the food life of the people. There is also urgency for knowing as much as possible about what is needed to improve the energy and nutritive value of the diets we hope to improve. Because there must be a balance among the supplies of the many nutrients, it is possible that the greatest need of many undernourished population groups is for additional foods. Increasing the supply of the indigenous food items usually provides added amounts of protein and other nutrients as well as energy. With sufficient calories, the protein may become adequate, especially for adults. This possibility must not be overlooked. When additional sources of protein are needed, priority should be given to food sources.

Cognizance must be taken of the advisability of adding the least amount of soy protein that can increase the protein supplies to the level of meeting the needs of an underfed population. To think that if "a little is good, more is better," is erroneous when applied to protein. Adding as little as 2 percent of soy protein to an indigenous food that is used regularly can mean a significant improvement in potential nutrient supply. Adding unnecessary amounts of soy protein not only limits the number of people who can be served from a given supply but can cause undesirable changes in the flavor and preparation characteristics of the cereal or flour or other product to which it is added. Also, soy protein is likely to be a much more expensive source of energy than indigenous foods. A lifetime

of malnutrition cannot be corrected by suddenly loading food with added nutrients. A malnourished body does not have the ability to utilize large amounts of protein and other nutrients thrust upon it until it has progressed well along the road to recovery.

Concurrently with well-considered actions to alleviate calorie-protein malnutrition, we must expand present and initiate new research that will lead to a better understanding of protein nutrition and how to meet human needs for protein and other nutrients.

IODINE, VITAMINS, MINERALS, AND PHYTIC ACID AS RELATED TO SOYBEAN PROTEIN

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Although the title suggests a rather diverse group of factors, there really is considerable similarity in the effects of soybean protein upon the mineral or vitamin requirements of animals. In general, it can be stated that unheated soybean protein does increase the animal's requirement for certain minerals and vitamins, as compared with heated soybean protein or some other sources of protein. Some of this effect may be due, in part at least, to the phytic acid contained in soybeans. A brief review of these factors will be presented.

Iodine

McCarrison (1933) reported that rats had a high incidence of thyroid enlargement when fed a diet containing raw soybeans. Iodine in large amounts did not correct this enlargement. On the other hand, Sharpless and coworkers (Table 1) from the Ford Hospital in Detroit (1939) showed that as little as 20 micrograms of iodine per kilogram of diet corrected the thyroid enlargement they obtained with a soybean-containing diet. They further showed that the goitrogenic factor was partly related to the fat content of soybeans and that it was destroyed by steaming, to a greater extent than by autoclaving.

Table 1.--Goitrogenic effect of soybeans on rats[1/]

Item	Weight thyroid mg./100 g.	Iodine percent
Soy basal (25 percent)	36	0.006
Soy + 20 µg. iodine/kg.	15	.015
Soy + 100 µg. iodine/kg.	12	.075
Stock diet	10	0.101
Soy basal	39	0.003
Ether extracted flour	21	.025
Autoclaved flour	28	.006
Steamed flour	19	0.009

1/ Sharpless, G. R., and coworkers, J. Nutrition 17: 545-555, 1939.

Wilgus and coworkers (1941) also showed (Table 2) that a small amount of iodine would correct the thyroid enlargement they obtained with expeller processed soybean meal. They also showed that their goitrogenic factor was insoluble in ethanol.

Table 2.--Goitrogenic effect of soybeans on chicks[1/]

Item	Weight thyroid mg./100 g.	Iodine in diet, µg./kg.
Practical + iodine	12	18,000
35 percent soybeans	100	38
15 percent casein	16	25
1.2 percent ethanol extracted	20	31
Ethanol residue	139	13
30 percent expeller soybean meal	59	19
30 percent expeller soybean meal + iodine	26	56

[1/] Wilgus, H. S., and coworkers, J. Nutrition 22: 43-52, 1941.

Possibly related to the goitrogenic factor, which increases the requirement for iodine, would be the antithyrotoxic factor in soybeans reported by Ershoff (1949). Many workers had used high levels of soybean meal in their attempts to isolate the animal protein factor from fish products, cow manure, liver meal and other materials. The high level of protein increased the vitamin B_{12} requirement. Other workers had used iodinated casein to accentuate the vitamin B_{12} requirement and found soybean meal to reduce thyroid size. How these factors are related are demonstrated in Table 3. Use of thyrotoxic principles reduced rat growth on the casein diet but not on the soybean diet. In another study where iodinated casein was given to all groups, vitamin B_{12} showed antithyrotoxic activity when used with low-fat soybean flour but not with casein. These data also show that the antithyrotoxic factor (or factors) was partly soluble in the oil.

More recently, Westerfield (1964) showed (Table 4) that the antithyrotoxic activity of soybeans for rats could be separated from a chick growth factor by an acid hydrolysis and acid precipitation process. This same process worked for the activity in liver residue, but not for cottonseed meal. In the latter the activity appeared to be more closely bound. This assay consisted of measurements for α-glycerolphosphate dehydrogenase activity where hemoglobin is the standard.

Table 3.--Antithyrotoxic principle in soybeans[1/]

Thyroactive supplement	Rat weight gain in grams in 28 days		
	Casein	Full-fat soy	Low-fat soy
None--Basal diet	101	102	
0.25 percent thyroid	61	107	
0.50 percent thyroid	45	105	
0.125 percent iodinated casein	59	103	
Basal (0.125 percent iodinated casein)	48		68
Vitamin B_{12}	52		93
Liver residue	103		99
Soybean oil	78		93

[1/] Ershoff, B. H., J. Nutrition 39: 259-281, 1949.

Table 4.--Antithyrotoxic activity of soybeans separated from growth factor[1/]

Item	Chick 4 wk. wt.	Antithyrotoxic activity by rats
Basal	227	--
Soy protein	281	20
Soy protein concentrate[2/]	223	22
Liver residue	290	32
Liver residue concentrate[2/]	221	34
Cottonseed meal	288	48
Cottonseed meal concentrate[2/]	270	42

[1/] Westerfield, W. W. and coworkers, J. Nutrition 83: 325-330, 1964.

[2/] Alkaline hydrolysis and acid ppt.

Vitamins

Most of the vitamin requirements for monogastric animals have been studied with diets containing some commercial soybean meal. Consequently, the standards set by the National Research Council should be adequate. However, it has been reported and confirmed that unheated soybean protein increases the vitamin B_{12} and vitamin D requirements. Although Balloun and Johnson (1953) reported unheated soybean meal to increase the blood clotting time and therefore perhaps increased the vitamin K requirement, Griminger and coworkers (1956) were unable to confirm this work. Griminger's suggestion was that use of the trichlorethylene extraction procedure may have induced the anticoagulant property.

Frolich (1954) showed that chicks fed underheated soybean meal grew faster when given vitamin B_{12}, whereas chicks on properly heated soybean meal did not respond to vitamin B_{12}.

At Washington State University, Carlson and coworkers (1964) showed that turkey poults fed an isolated soybean protein-glucose type diet grew poorly and suffered severe rickets though the diet contained normally adequate levels of vitamin D_3, calcium and phosphorus (Table 5). Growth and tibia ash were improved with twofold and fourfold increases of vitamin D_3, or by the replacement of 37-1/2 percent of the soybean protein with heated soybean meal protein or by the direct addition of 5 percent soybean brew flakes. The apparent response to vitamin D_3 when used with the soybean meal treatments was not significant. A further study showed that when two-thirds of the heated soybean meal was replaced by soybean brew flakes in a practical-type diet an increased need for vitamin D_3 for maximum growth was apparent (Table 6).

Table 5.--Effect of heated and raw soybean meal on vitamin D_3 requirement of poults on isolated soybean-type diet[1/]

	Vitamin D_3, I.U./kg.			
Diet	880	1760	3520	7040
	(Weight at 4 weeks)			
Basal	382	449	510	--
Heated soybean meal, 30 percent	534	597	627	--
Raw soybean meal, 5 percent	--	549	588	575
	Tibia ash, percent			
Basal	33.6	37.6	40.4	--
Heated soybean meal, 30 percent	44.0	46.1	46.7	--
Raw soybean meal, 5 percent	--	42.6	44.2	44.7

1/ Carlson, C. W. and coworkers, J. Nutrition 82: 366-370, 1964.

Table 6.--Effect of replacing heated with raw soybean meal on the growth response to vitamin D_3[1/]

Raw soybean meal, percent	Vitamin D_3 level, I.U./kg. 880 g.	4400 g.	8800 g.
0	452	440	428
10	429	445	414
20	379	374	363
40	308	359	360
60	290	302	321

1/ Carlson, C. W. and coworkers, J. Nutrition 82: 507-511, 1964.

Certainly the major effect in this experiment was the growth depression obtained from the soybean brew flakes, but the response from vitamin D_3 was significant at the 40 percent level of replacement.

This work led to the conclusion that soybeans contain both antirachitic and rachitogenic activity. The antirachitic activity is heat stable whereas the rachitogenic activity can be destroyed by heat. An example of the latter is given in Table 7, where autoclaving reduced the serum alkaline phosphatase activity and where vitamin D_3 reduced the enzyme activity with the untreated protein.

Table 7.--Effect of autoclaving isolated soybean protein and levels of vitamin D_3 on serum alkaline phosphatase activity[1/]

Vitamin D_3 level I.U./kg.	Untreated protein	Autoclaved protein	Mean
880	237	73.1	155
1760	157	39.4	98
3520	101	62.0	82
Mean	165	58	--

1/ Thompson, O. J. and coworkers, Poultry Sci. 45: 1966 (in press).

The amount of heat needed to completely destroy this activity may be in excess of 60 minutes of autoclaving at 120° C. as shown by the data in Table 8. In this experiment the fourfold level of vitamin D_3 was not significantly better than two times the N.R.C. recommendations. However, with each increment of autoclaving time, enzyme activity was reduced. The procedure for autoclaving involved spreading the dry protein powder in pans at 3 to 5 cm. depth, steaming to 100° C., then closing the autoclave and maintaining 120° C. for the desired time. Further studies are underway by using autoclaving times up to 240 minutes. It can be stated at this time that over 80 minutes destroyed some protein value as growth was reduced; however, bone ash was not lowered.

Using chicks as the experimental animal, Jensen and Mraz (1966) reported that both calcium and phosphorus were required to overcome rachitogenic activity of isolated soybean protein(Table 9). Either mineral alone was not effective.

Table 8.--Effect of length of autoclaving time on serum alkaline phosphatase[1/]

Autoclaving time, minutes	Vit. D_3 level I.U./kg. 1760	3520	Mean
0	163	159	161
20	153	123	135
40	131	113	122
60	96	99	98
Mean	136	124	

1/ Thompson, O.J. and coworkers, Poultry Sci. 45: 1966 (in press).

Table 9.--Levels of calcium and phosphorus with soy protein for chicks[1/]

Supplement Ca	P	Average gain, g.	Tibia ash, percent
0	0	143	37.8
1.2	--	133	35.0
0	0.6	113	37.1
0.3	0.15	147	42.0
0.6	0.30	148	42.4
1.2	0.60	138	43.1
Casein-gelatin		142	45.8

1/ Jensen, L.S. and Mraz, F. R., J. Nutrition 89: 471-476, 1966.

The combination of calcium and phosphorus was not as good as the casein-gelatin diet; however, this indicated that all of the rachitogenic activity was not overcome. Chelating agents were of no value in their work. Similar results have been obtained at South Dakota State University.

With baby pigs, Miller and coworkers (1965) showed that isolated soybean protein increased the vitamin D_2 requirement (Table 10). Although a tenfold increase in vitamin D_2 supported normal growth, and reduced alkaline phosphatase activity to normal levels, calcium retention was still inferior to that with a casein diet.

Table 10.--Effect of soy protein on vitamin D_2 for baby pigs[1/]

	D_2 level I.U./kg.	Average daily gain, kg.	Casein retention, percent	Serum alk. phos. 5 weeks B-L units
Soy basal	50	0.20	--	13
	100	.22	74	12
	250	.22	75	7
	500	.25	71	7
Casein	0	.15	72	21
	50	.25	--	7
	100	0.25	87	9

[1/] Miller, E. R. and coworkers, J. Nutrition 85: 347-354, 1965.

Minerals

Reports from Cornell University have dealt with a factor in soybean meal, which increases the availability of phosphorus for turkey poults on an isolated soybean protein-type diet. Griffeth and coworkers (1966) have shown (Table 11) that anhydrous dicalcium phosphate is made more available by soybean meal. Even with the hydrated product tibia ash is slightly improved and growth is greatly improved by soybean meal. They find the phosphorus availability factor to be nonextractable by water, but that the growth factor is water or methanol soluble (Table 12). Several reports by Kratzer and colleagues at the University of California have dealt with a growth factor(s) in soybean meal which is water-, methanol-, or benzene-soluble.

Table 11.--Effect of soybean meal on phosphorus availability for turkey poults[1/]

Diet (0.6 percent P)	Weight, grams	Tibia ash, percent
Isolated soy--anhy:PO_4	185	29
Isolated soy--hyd:PO_4	294	45
Soybean meal--anhy:PO_4	455	42
Soybean meal--hyd:PO_4	490	48

[1/] Griffeth, M. and coworkers, Poultry Sci. 45: 189-199, 1966.

Table 12.--Growth factor in soybean meal for turkey poults[1/]

Supplement	Wt.-3 weeks
Basal	400
Water extract ≈ 20 percent S.B.F.	482
Methanol extract of 44 percent S.B.M.	490
20 Percent soybean flakes, heated	546

[1/] Griffeth, M. and Young, R. J., J. Nutrition 89: 293-299, 1966.

Other work from California by Davis and coworkers has shown that isolated soybean protein increases the requirement for several trace minerals. The use of chelating agents such as ethylenediamine tetraacetic acid (EDTA) reduced the mineral requirements. Data are shown in this regard for manganese (Table 13), copper (Table 14), and zinc (Table 15). In the case of iron deficiencies, no responses from EDTA were obtained, which indicated that EDTA was not in itself growth stimulatory.

Phytic Acid

O'Dell and Savage (1960) suggested that since soybean protein contains about 0.5 percent phytic acid phosphorus, perhaps it was binding the trace minerals.

Table 13.--Effect of EDTA on manganese (Mn) requirement for chicks on isolated soy protein[1/]

Supplement	Relative wt., percent
None	100
5 mg. Mn/kg.	124
10 mg. Mn/kg.	131
25 mg. Mn/kg.	131
EDTA, 0.07 percent	120
EDTA, 0.07 percent + 5 mg. Mn/kg.	136

[1/] Davis, P. N. and coworkers, J. Nutrition 77: 217-223, 1962.

Table 14.--Effect of EDTA on copper (Cu) requirement of chicks on isolated soy protein[1/]

Supplement	Relative wt., percent
Basal	100
2 mg. Cu/kg.	105
4 mg. Cu/kg.	108
EDTA, 0.07 percent	109
2 mg. Cu/kg.	106

[1/] Davis, P. N. and coworkers, J. Nutrition 77: 217-223, 1962.

Table 15.--Effect of EDTA on zinc (Zn) requirement for chicks on isolated soy protein[1/]

Supplement	Relative wt., percent
None	100
5 mg. Zn/kg.	154
10 mg. Zn/kg.	233
30 mg. Zn/kg.	297
EDTA 0.07 percent	293
EDTA 0.07 percent + 5 mg. Zn/kg.	331

[1/] Davis, P. N. and coworkers, J. Nutrition 77: 217-223, 1962.

They also showed the zinc requirement to be greater with an isolated soybean protein diet than with a casein-gelatin diet for chicks (Table 16). But in addition, they showed that phytic acid could be complexed with casein to increase the zinc requirement. To accomplish this, phytic acid at 5 percent was mixed with casein and slurried overnight. Further adverse effects were obtained when phytic acid at 4 percent was slurried with soybean protein. Calcium phytate added directly to the dry diet was largely ineffective. This is certainly good evidence that phytic acid could be the factor in soybean protein which increases the trace minerals requirement.

Table 16.--Effect of a phytic acid--protein complex on the need of chicks for zinc[1/]

Supplement	Wt. at 4 weeks in grams	
	Casein-gel basal	Soy protein basal
Basal	454	142
15 p.p.m. Zn	--	387
55 p.p.m. Zn	458	457
Phytic acid-complex	180	96
Phytic acid-complex + 55 p.p.m. Zn	434	214
1.2 percent Ca Phytate	438	--
1.2 percent Ca Phytate + 55 p.p.m. Zn	476	--

[1/] O'Dell, B. L., and Savage, J. E., Proc. Soc. Exp. Biol. Med. 103: 304-306, 1960.

However, a more recent report by Likuski and Forbes (1964) has shown (Table 17) that the slurry procedure was not necessary under their conditions nor was protein required. Phytic acid added to either an amino acid or casein diet greatly reduced growth by tying up the zinc. EDTA at 223 p.p.m. largely overcame the growth retardation but only brought the zinc content of tibia ash partway back to normal.

Table 17.--Phytic acid complexes with amino acids[1/]

Diet	Average daily growth g.	µg Zn g. ash
Amino acid	11.9	286
Amino acid + 1.8 percent phytic acid	5.9	127
Amino acid + 1.8 percent phytic acid + EDTA	10.1	172
Casein	13.5	305
Casein + 1.8 percent phytic acid	7.9	126
Casein + 1.8 percent phytic acid + EDTA	12.5	233

[1/] Likuski, H. J. A. and Forbes, R. M., J. Nutrition 84: 145-148, 1964.

Discussion and Summary

Jensen and Mraz (1966) had suggested that the rachitogenic activity of isolated soybean protein might be due to phytic acid. However, EDTA or other chelating agents were of no effect in their work, nor was EDTA of value earlier (Carlson, 1964). Sodium phytate did not alter the growth of tibia ash obtained on a casein-gelatin diet in this latter work. Whether or not phytic acid is really involved in the rachitogenic activity of isolated soybean protein remains to be determined.

In summary, unheated soybean protein has been shown to increase the requirements for iodine, vitamin B_{12}, vitamins D_2 or D_3, phosphorus, calcium and phosphorus, zinc, manganese and copper. Small amounts of iodine or vitamin B_{12} will correct for their increased requirement; however, relatively large amounts of the other nutrients must be used to obtain normal growth and bone composition. Use of EDTA in the case of the trace minerals or heating the protein in the case of vitamin D_3, calcium and phosphorus corrects for their increased requirements.

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PHYSIOLOGICAL EFFECTS OF SOYBEAN FRACTIONS

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Although a number of factors have been considered responsible for flatulence and discomfort in the gastrointestinal tract (1, 2), the association between the consumption of certain bean products and the presence of flatulence appears to be the most prevalent. Products containing dry beans, lima beans, and soybeans are prominent in this category.

The purpose of this report is to describe the methods that have been used to locate the site of gas production along the gastrointestinal tract following the ingestion of various soybean meal fractions, and also to suggest possible mechanisms that may be involved in its production. In these studies, observations were made on both man and animals. The use of the latter was necessary when the identification of specific areas of action along the gastrointestinal tract demanded techniques that could not conveniently be used on man. The approaches used and objectives that were realized will be described under the following topical headings.

1. Observations on flatus production in human subjects

In order to test the effectiveness of various soybean fractions on flatus production in man, a comparison was made between the effects of a basal nongas-producing diet and one in which approximately a third of the daily diet was composed of a selected soybean fraction. The soybean meal to be tested was consumed in the form of mush and muffins that were equally divided among all three meals in the day. Both the basal diet and the experimental soybean diets contained approximately the same caloric values; and the distribution between the carbohydrate, fat, and protein were adjusted as closely as possible. When the experiment was being run, the subjects consumed the basal diet for 6 consecutive days followed by another 6-day period on the experimental soybean diet. An adequate vitamin supplement was consumed each day. No deviation from the routine consumption of fixed amounts of food at each meal was allowed during the entire 12-day test period.

Flatus collections were usually made on the fourth and sixth day after each dietary regimen was started. This was done to allow sufficient time for nutritional and digestive adjustments to be made. The time assigned for making the collections were for 2 hours after lunch and again for 2 hours after dinner on the same day. With the subject lying comfortably on a hospital cot, the rectal flatus was collected by inserting a lubricated catheter through the anus and approximately 15 cm. into the rectum. The catheter was perforated with a number of 1-cm. holes for 7 cm. back from the tip. The open end of the catheter was attached to two calibrated collection

cylinders containing a displacing solution of saturated sodium sulfate in 5 percent sulfuric acid. The flatus produced during the first hour was collected in the first cylinder and that produced during the second hour was collected in the second cylinder. (See Fig. 1.) The first flatus passed was collected in a reserve container so as not to contaminate the passed flatus with room air. After the total flatus volume was recorded at the end of a collection period, the percentage composition of the flatus was recorded for carbon dioxide, oxygen, hydrogen, and nitrogen by means of a Fisher-Clinical Gas Partitioner.

The results of this type of experimentation demonstrated that the flatulence producing factor in soybeans does not reside in the hull, fat or protein fraction, but is in some way associated with the low molecular weight fraction of the carbohydrates present in the soybean (3).

2. Location of site of gas production in animals (in vivo technique)

To establish the site of gas production along the gastrointestinal tract, an experimental procedure was instituted in which a number of isolated loops of the intestine and colon were prepared in the anesthetized dog. This was done by inserting fistulae into the two ends of the duodenum, jejunum, ileum, and colon. The loops were separated from each other by means of ligatures (see Fig. 2). Each loop was flushed with physiological saline, and then a known quantity of soybean meal slurry was injected into each loop and the fistulae were closed. At various intervals after the soybean slurry had been injected, the material was collected along with any gas that had been produced, and the volumes of each were recorded. The gas samples were analyzed for gaseous composition by the Fisher-Clinical Gas Partitioner.

The results of the in vivo procedure showed that gas production, in the dog, can occur in the duodenum, as well as in the lower ileum and colon. The amount of gas production in the intestine and colon is graduated, the colon being far more productive in quantity than the duodenum. It was also observed that the time for the beginning of gas production was on the average around 2 to 3 hours, with the maximum rate of production being around the fifth or sixth hour after the start of the experiment.

Just as in the human experiments, the carbon dioxide content of the collected samples was always considerably higher than when an inert substance such as methyl-cellulose was used. It was also observed that when the animals used were pretreated with an antibiotic or the bean slurry injected into the intestinal loop contained an antibiotic, the amount of flatus produced was markedly inhibited (4). This along with the observation that carbon dioxide production is markedly increased when bean slurries are introduced into the intestinal and colon loops lead to the conclusion that the presence of the bacterial flora along the gastrointestinal tract play an important role in flatus production. This observation was responsible for directing our attention to a study of the role of various types of bacteria in the production of flatus while consuming various soybean products.

3. The association of the bacterial flora and gas production (in vitro technique)

The relationship between the bacterial flora and fermentation processes in the colon have often been suggested as a possible source of gas production (5, 6). However, the nature of this process and the type of organisms involved still remain somewhat of an unsolved problem. The results of preliminary experiments soon demonstrated that the gas production resulting from the ingestion of soybean products was not associated with the E. coli aerobic bacteria present in the gastrointestinal tract, but that there was a close relationship between the anaerobic clostridium, or spore forming, strain of organisms normally found in the gastrointestinal tract. To establish the validity of the hypothesis the following procedures were undertaken (see Fig. 3).

Sterile swabs of the mucosal membranes of various areas of the small intestine and colon were transferred to separate tubes containing a thioglycollate media and heated to 80° C. for 30 minutes. This procedure kills the aerobic bacteria and serves as a good media for the anaerobic organisms to grow. Samples of each tube were further cultured in another thioglycollate solution and allowed to grow at 37° C. for 24 hours. Then a 1-ml. sample of the anaerobic bacteria was added to a 5-ml. sample of the soybean fraction in a 20-ml. syringe. After thoroughly mixing the bacteria and the soybean product, the syringe was stoppered and placed in a 37° C. water bath with the syringe plunger directed upward. Thus, any gas that was produced could be measured, and when desired, samples of the produced gas could be collected and its gaseous composition determined. This in vitro technique afforded an opportunity to determine the gas-producing ability of various soybean fractions quite easily and has proven to be an excellent method for screening various products with only the slightest amount of technical skill.

The results of this technique to locate the gas-producing fraction in soybeans will be reported by Dr. Rackis in a paper which is to follow. Suffice it to say again, that all of our experiments with this technique point to the fact that the gas-producing fraction is in some way associated with the low molecular weight carbohydrate compounds in the soybeans. This fraction may contain such sugars as glucose, levulose, galactose, and sucrose, as well as relatively large amounts of the oligosaccharides raffinose and stachyose. Although it can be demonstrated by the in vitro and in vivo techniques described above that the anaerobic bacteria do produce gas in the presence of mono- and disaccharides, it does not seem logical that they contribute much to the normal gas-producing process in the intact animal because they are so readily digested and absorbed in the duodenum and ileum and thus never reach the lower portion of the gastrointestinal tract where most of the bacteria are found.

Although preliminary experiments with the in vitro and in vivo technique show that raffinose and stachyose do not contribute much in the way of gas

production when exposed to anaerobic chlostridium organism, it does seem logical that they must in some way be associated with the mechanism of gas production when consumed as part of the soybean product. The fact that there are no known enzymes in the upper intestinal tract normally available for their digestion to mono- and disaccharides does not preclude the possibility that there may be other mechanisms at work in the gastrointestinal tract that could make them available for gas production by the anaerobic bacteria normally present in high concentrations in the lower ileum, caecum, and colon portions of the gastrointestinal tract.

4. Proposed research to establish whether or not raffinose or stachyose can serve as a source of gas production in the gastrointestinal tract

Preliminary experiments have shown that if raffinose or stachyose have previously been hydrolyzed with hydrochloric acid, there is a tendency for the fraction to be made more susceptible to attack by the anaerobic bacteria, with a resulting increase in gas production. This observation has served as a challenge to further investigate the possibilities of the role of raffinose or stachyose as a source of gas production. The following problems present themselves for further study. They are (1) presence of an enzyme system in the caecum or colon that might digest the raffinose or stachyose on down to mono- or disaccharides and thus make them available for an effective action of the anaerobic bacteria; (2) hydrochloric acid in the stomach might contribute to the hydrolysis of the raffinose or stachyose so that they can more effectively be acted upon by the bacteria in the lower ileum and colon; (3) there might be still another bacterial mechanism present in the digestive tract that could play an important role in preparing the raffinose or stachyose for effective action by the chlostridia bacteria.

Experiments are now in progress to test the potentialities of the above proposals. It is hopeful that at least one of the proposals might lead to a better understanding of the exact mechanism by which soybean products contribute to the problem of gas production.

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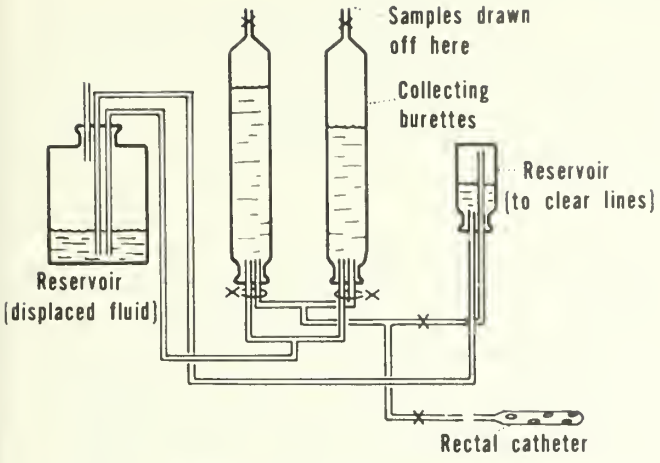

Figure 1. Apparatus for collecting human flatus

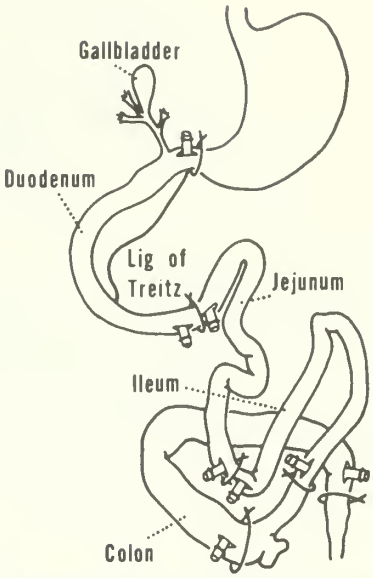

Figure 2. Method used to investigate the formation of gas in isolated intestinal segments

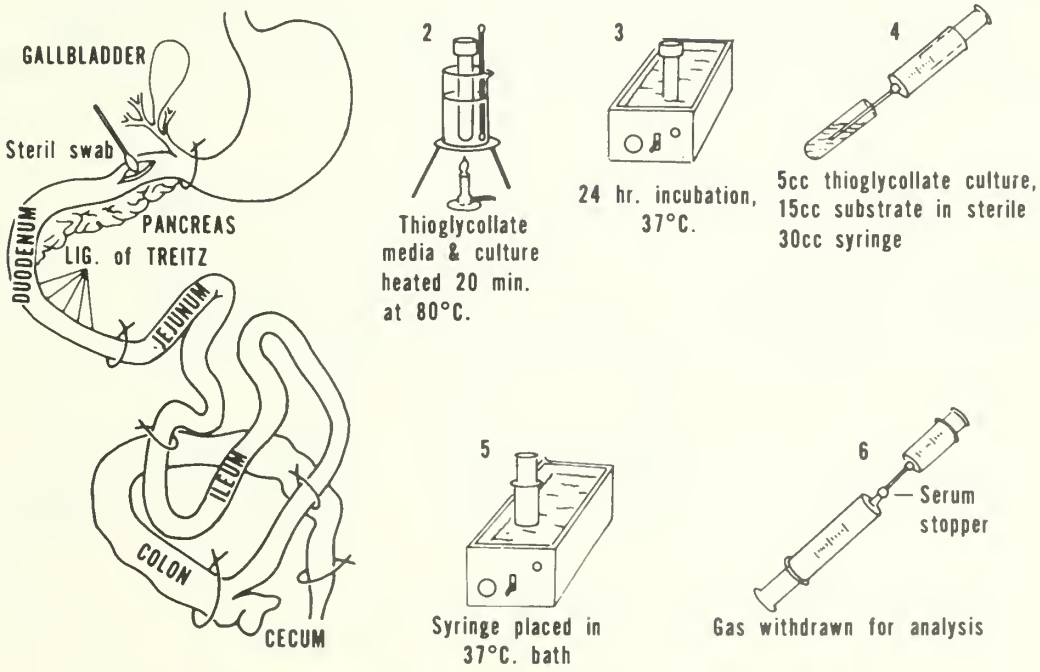

Figure 3. Method used to investigate the role of the canine microflora in the production of gas

ISOLATION AND CHARACTERIZATION OF FLAVOR AND FLATULENCE FACTORS IN SOYBEAN MEAL[1]

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Flavor and flatus are two problems that affect the use of soybeans for food. With soybeans becoming an increasingly important source of high-quality protein, knowledge of the nature of constituents in soybeans that are associated with flavor and flatulence is also increasingly important. In these studies, dehulled defatted soybean meal was prepared at the Northern Laboratory from certified seed-grade soybeans. In some experiments, soybean meal was treated with live steam at 100° C. This treatment with live steam is referred to as toasting.

Flavor[2]

Reports from industry have indicated that flavor components present in soy flour, protein isolates, and concentrates may affect consumer acceptance of some products containing them. Table 1 lists some of the most common flavor characteristics of dehulled defatted soybean meal (1) and indicates the influence of live steam on these flavors.

Table 1.--Flavor of soy flour: effect of steaming

Steaming, min.	Flavor score[1]	Flavor description			
0	1.5	Beany	Bitter	Green	
3	4.5	Beany	Bitter	Nutty	Sweet toasted
10	6.0	Beany	Nutty	Bitter	Toasted sweet
20	6.3	Beany	Nutty	Bitter	Toasted sweet
40	6.1	Beany	Nutty	Bitter	Toasted sweet

[1] 1 = Strong; 10 = bland.

[1] Part of collaborative work on flatulence was carried out by F. R. Steggerda, University of Illinois, Urbana, Illinois, under contract with the U.S. Department of Agriculture and authorized by the Research and Marketing Act of 1946.

[2] Presented in part at Second International Congress on Food Science and Technology, Warsaw, Poland, August 22-27, 1966.

Raw meal is usually described as tasting beany, bitter, and green. The green taste disappears within 3 minutes of steaming at atmospheric pressure. The beany-bitter flavor, together with nutty, sweet, and toasted flavors, varies in intensity with continued steaming. Flavor scores of 6.0 to 6.3 for toasted soybean meal may limit its use in some applications. The data show flavor scores were not improved by steaming longer than 10 minutes; this steaming time is approximately that required to achieve the maximum nutritive value (2). An astringent hydrocarbonlike flavor, together with an aftertaste, is detected in many soybean protein products that have been extensively processed.

The procedures used in extracting flavors of dehulled defatted soybean meal with hot 95 percent ethyl alcohol and with an azeotropic mixture of hexane: absolute ethyl alcohol (79:21) are shown in Fig. 1. The residues are bland as judged by taste tests. In the ethyl alcohol procedure, the meal was first washed with peroxide-free diethyl ether to remove small amounts of residual free lipids and to minimize oxidative degradation of lipids during subsequent processing. The free lipid fraction (1a) was obtained in yields of about 1 percent and had practically no odor or flavor. These lipids are very stable to air oxidation and heat, as judged by odor and taste. The ether wash did not change either the intensity or the flavor characteristics of the original meal.

Alcohol solubles were concentrated and treated with acetone; then the resulting precipitate was discarded. The supernatant was concentrated under vacuum to a sirup at 40° C., freeze-dried, and finally extracted with diethyl ether to yield two fractions having intense flavors [fractions (1c) and (1d)]. The lipids in fraction (1c) will be referred to as bound lipids to differentiate them from the lipids present in fraction (1a). Presumably, the bound lipids are associated with protein and carbohydrates in the meal, through hydrophobic and hydrogen bonds. Free and bound lipids corresponding to fractions (1a) and (1c) of Fig. 1 were extracted simultaneously by an hexane-ethyl alcohol azeotrope mixture. The extracted material had flavor characteristics of fraction (1c).

The fractions were first chromatographed on silica gel plates developed with a petroleum ether:diethyl ether:acetic acid solvent mixture (90:10:1). Color development was obtained by charring with 50 percent sulfuric acid. Trace amounts of hydrocarbon were detected only in the patterns of the free lipid fraction. All fractions, except residue (1d), contained small amounts of triglyceride. The bulk of the material remained on the baseline in the patterns of all fractions.

The constituents in the baseline material were effectively resolved with chloroform:methanol:water (65:25:4) as the solvent system. Thin-layer chromatographic patterns of fractions (1b), (1c), and (1d) on silica gel

are shown in Fig. 2. RG-lecithin, a commercial preparation of soybean phospholipids, was used for comparative purposes. Components (a) and (b) in all fractions represented a mixture of inositides, carbohydrates, and unknown substances. Components (c) and (d) correspond to lecithin and cephalin, respectively. The presence of phospholipids in components (a) through (d) was verified by color tests and by elution and subsequent determination of the phosphorous content of these components (3, 4). Components (e), (f), and (g), which turn purple with 50 percent H_2SO_4, correspond to the sterol glycosides, sterol glycoside-fatty acid esters, and free sterols, respectively (5). The sterols exist as a mixture of stigmasterol, β-sitosterol, and campesterol (5). The chromatographic pattern of fraction (1a) was practically identical to that of the bound lipids of fraction (1c), except that the triglyceride and hydrocarbon components of fraction (1a) were masked by the solvent front.

Except for the presence of more unknown baseline material in the pattern of acetone-alcohol solubles (1b); the chromatogram is similar to that of RG-lecithin. In contrast, the patterns of RG-lecithin and fraction (1c) are nearly identical. Residue (1d) contains small amounts of phospholipid and is primarily composed of unknown baseline material. The faster moving components are present in trace amounts and correspond to components (d) and (g).

In spite of the similar chromatographic behavior seen in Fig. 2, the flavor characteristics of the fractions are quite different. For example, RG-lecithin has a pleasant, nutty flavor. The bound lipid fraction (1c) has strong hydrocarbon flavor and a persistent aftertaste, whereas, residue (1d) is intensely bitter. The acetone-alcohol solubles (1b) possess the flavors of fractions (1c) and (1d) with the bitter taste predominating. Solubility behavior, chemical analysis, and chromatographic properties of these fractions indicate that the major flavor principles of defatted soybean meal are associated with both lipid and nonlipid constituents. Laboratory personnel were used to describe the flavor characteristics of various meal fractions and their findings are summarized in Table 2.

Table 2.--Flavor characterization of various soybean meal fractions

Fraction[1/]	Flavor	Mouth-feel
1a	None	Oily, waxy
1b	Bitter, hydrocarbon, sweet, lingering aftertaste	Oily, biting, throat-catching
1c	Hydrocarbon, lingering aftertaste	Oily, biting, throat-catching
1d	Intensely bitter, mealy, sweet	None
RG-lecithin	Nutty	Oily, waxy

1/ See Fig. 1 for identification of fractions.

Results were the same when toasted soybean meal was also extracted as diagrammed in Fig. 1. More detailed fractionation procedures resulted in the isolation of substances having metallic, green, grassy flavors.

Only trace amounts of phenolic acids are present in the fractions that possess the soybean flavors. Defatted soybean meal contains several phenolic acids (7) and are reported to contribute to the flavor of soybeans because of their phenolic character (7). Our tests indicate that the phenolic acids have very little taste. Furthermore, only trace amounts of phenolic acids are present in the fractions that have the characteristic soy flavors.

Soybean saponins have been frequently reported in the literature as tasting bitter. We have found that highly purified saponins, isolated according to Birk and others (8) have no taste. This absence of taste would imply that impurities in some saponin preparations contained the bitter principle.

To determine the presence of volatile constituents as a possible source of derived flavors and to measure oxidative degradation of lipids, dehulled defatted soybean meal was subjected to vacuum distillation for 8 hours at 70° C. Volatile carbonyls were trapped and converted into 2,4-dinitrophenylhydrazone derivatives. The derivatives were chromatographed on silica gel, eluted, and analyzed by ultraviolet spectroscopy (6). The primary carbonyls detected were ethanal, acetone, hexanal, and dienal (Table 3).

Table 3.--Volatile carbonyl content of defatted soy flour

2,4-Dinitrophenyl hydrazine derivative	λ_{max}	Content in soy flour[1]
	mμ.	p.p.m.
Ethanal	354	0.11
Acetone	362	0.25
n-Hexanal	356	3.2
Dienal[2]	390	--

[1] Vacuum distillation, 70° C., 8 hours.

[2] Based on the development of a purple color after spraying chromatogram with alkali.

Preliminary gas-liquid chromatographic studies also indicate that only a small number of volatile constituents were obtained by vacuum distillation. Quantitative analyses showed that the total volatile carbonyl content of soybean meal was about 3.6 p.p.m. In our taste tests, 3 p.p.m. of hexanal in water has neither the odor nor the flavor of raw meal. These data indicate that oxidative degradation of lipids in soybean meal prepared in our laboratory was minimal and that the volatile carbonyls, assuming effective removal by vacuum distillation, do not contribute significantly to the flavor of the soybeans. Fujimaki and others (6) have reported that many volatile carbonyls are present in full-fat soy flour but the amounts present in defatted soy flour were greatly reduced.

Flatulence[3/]

Human studies have shown that toasted dehulled full-fat and defatted soy flour cause flatulence (9). Comparatively large amounts of materials are needed in the human studies but Richards and Steggerda (10) have reported good results with *in vivo* tests with dogs. They found increased gas volumes, with greatly increased concentrations of carbon dioxide and hydrogen, produced in dog intestines by anaerobic microflora when incubated with navy bean homogenates. Our report describes research on the use of *in vitro* cultures of anaerobic bacteria of the dog colon as an assay for determining the nature of the flatulent factors in soybean meal. This *in vitro* assay requires much less material and is much faster. Correlation between *in vitro* gas production and *in vivo* flatulent activity in isolated intestinal segments of anesthetized dogs was also studied.

The procedure used in the extraction and preparation of meal fractions for analyses of flatulent activity is shown in Figs. 3 and 4. The extraction procedure outlined in Fig. 4 was based on previously reported evidence that low-molecular-weight constituents of soybean meal, extracted with 80 percent ethyl alcohol, are primarily responsible for soybean flatulence in man (9).

In vitro gas production of various soybean meal fractions incubated with cultures of anaerobic microflora of the dog colon is given in Table 4.

Navy bean flour, soy flour, and whey solids produced gas, with an average composition of 40 percent carbon dioxide and 52 percent hydrogen. Little gas was produced with the water-insoluble residue (75 percent polysaccharide, 25 percent protein), and the soy protein isolate was inactive. These *in vitro* results, therefore, correlated very well with data previously obtained with human subjects. Results were similar with the procedures of Richards

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3/ Presented in part at the 26th Annual Meeting, Institute of Food Technologists, Portland, Oregon, May 22-27, 1966.

and Steggerda (10) in isolated intestinal segments of the dog. Furthermore, the in vitro assay satisfied two criteria for flatulence--a high gas volume and a large concentration of carbon dioxide and hydrogen.

The in vitro assay was used to follow the aqueous alcohol extraction of meal constituents having flatulent activity (Table 5). Although no gas was produced with the 95 percent ethanol solubles, however, the flatulent factor was extracted, since fractions (4b) and (4c) produced 1.7 to 5.0 cc. gas per hour compared with 2.0 cc. with soybean meal. The absence of flatulent activity in fractions (4a) and (4d) was attributed to the presence of a microbial growth inhibitor (11).

Table 4.--In vitro gas production by cultures of the microflora of the dog colon

Product[1/]	Gas volume, cc./hr.	Average composition of gas, percent
Navy bean flour	20	CO_2 40 ± 5
Soybean meal	13	H_2 52 ± 3
Whey solids	9	O_2 2
Water-insoluble residue	2	N_2 6
Soy protein isolate	0	

1/ One-gram sample.

The constituents that inhibit gas production can be removed by absorption on polyamide columns. For example, after absorption of fraction (4d) on polyamide, water was used to elute material high in carbohydrate content (fraction 4e). Flatulent activity of this fraction was high. Practically all the ultraviolet absorbing and fluorescing constituents of fraction (4d) were retained by the polyamide. Fractions (4f) and (4h), representing the 80 percent and 60 percent ethanol extractions, were also active gas producers. Residue fraction (4i) containing 72 percent protein, with the remainder primarily polysaccharides, was devoid of activity. Chemical analyses indicated that the active flatulent fractions contained appreciable amounts of carbohydrates as glucoside derivatives and oligosaccharides. These results showed that carbohydrates appeared to be the primary substrates that were fermented to produce gas.

Table 5.--Extractability of the flatulent factor with aqueous ethanol

Fraction number	Soybean fraction[1,2]	Yield (g./100 g.meal)	Carbohydrate content (as percent glucose)	Gas volume, (cc./hr./ g.)
	Soybean meal	--	--	2.0
4a	95 Percent ethanol solubles	18.1	82	0
4b	Cold precipitate	3.9	93	5.0
4c	Acetone precipitate	6.5	86	1.7
4d	Acetone solubles	7.7	80	0
4e	Neutral fraction (polyamide)	--	80	4.0
4f	80 Percent ethanol solubles	3.4	55	2.2
4h	60 Percent ethanol solubles	4.2	22	2.3
4i	Residue[3]	74.3	--	0

1/ See Fig. 4 for identification of fractions.

2/ A 0.5-g. sample used for assay.

3/ Contains 72 percent protein (N x 6.25), 25 percent polysaccharides by difference.

In vitro gas production from various carbohydrates is shown in Table 6. Galactose, sucrose, and dextrose produce large volumes of gas, high in carbon dioxide and hydrogen contents. Raffinose and stachyose produced much smaller amounts of gas in the same time period. Unpublished data, however, have shown that raffinose and stachyose hydrolyzed with yeast invertase and acid produced large amounts of gas. Arabinose produced no gas. Dehulled defatted soybean meal contains 15 percent water-soluble carbohydrates, such as sucrose, raffinose, and stachyose (12).

Soybean meal contains several phenolic acids (7) as well as isoflavonoids. Preliminary experiments have shown that ferulic and syringic acids were able to inhibit completely in vitro gas production of soybean meal, carbohydrates, and other substrates. Genistin, an isoflavone glycoside, was much less effective.

Effect of plant phenolics on in vivo flatus production is shown in Table 7. Results indicate that ferulic and syringic acids inhibit flatus activity in both the ileum and colon. In separate experiments, 45 mg. of ferulic acid per kilo of body weight was required to inhibit flatus activity completely in the ileum.

Table 6.--*In vitro* gas production with carbohydrate substrates

Substrate	Gas volume,[1] cc.
Sucrose	18.0
Galactose	15.0
Dextrose	13.0
Raffinose	2.5
Stachyose	3.0
Arabinose	0
Control[2]	0

[1] A 0.5-g. sample incubated for 24 hours with cultures taken from the dog colon.

[2] Made up of 15 ml. thioglycollate media + 5 ml. culture.

Comparative *in vivo* and *in vitro* results for various oilseed flours are shown in Tables 8 and 9. Dehulled defatted soybean, cottonseed, and peanut flours, all produced nearly comparable amounts of gas in these tests.

Summary

The flavors of dehulled defatted soy flour are readily extracted with 95 percent ethyl alcohol or with an azeotropic mixture of hexane:absolute ethyl alcohol (79:21). Constituents in both the lipid and nonlipid fractions are responsible for the characteristic flavor of soybean products. The soy flavor profile is composed of several components, which have been separated into fractions designated as tasting metallic, green-grassy, intensely bitter, and hydrocarbon-astringent. Contrary to literature reports, our chromatographic analyses, chemical tests, and taste tests show that the phenolic acids of soybeans and highly purified soy saponins have no taste.

Dehulled defatted soybean meal prepared in our laboratory from seed-grade soybeans contains approximately 3.6 p.p.m. of volatile carbonyls. The carbonyls, identified as their 2,4-dinitrophenylhydrazone derivatives, were hexanal, acetone, ethanal, and a dienal. Hexanal, the major volatile carbonyl, at 3 p.p.m. in water, has neither the odor nor the flavor of raw meal. These data also indicate that little degradation of lipids by lipoxidases, peroxidases, and air occurred during preparation.

Table 7.--Effect of plant phenolics on *in vivo* gas production

Substrate[1]	Conc. phenolic,[2]	Time of inc. hrs.	Ileal loop			Colon loop		
			Gas vol.	Gas, % CO_2	Comp., % H_2	Gas vol.	Gas, % CO_2	Comp., % H_2
Soybean meal[3]	0	9	78	32	43	30	33	16
Soybean meal	0	9	94	43	43	18	45	7
Soybean meal	0	9	94	25	61	35	12	24
Soybean meal + ferulic acid	30	10	--	--	--	0	0	0
Soybean meal + syringic acid	20	8	2	17	0	6	11	35
Soybean meal + genistin	60	9	35	30	35	--	--	--

[1] Composed of 6 g. of dehulled defatted soybean meal homogenate.

[2] Milligram per kilo of body weight.

[3] Average values of six experiments.

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Table 8.--Flatulent activity of oilseed flours in intestinal segments of dogs

Oilseed flour[1/]	Average gas volume, cc./8 hr.	
	Ileum	Colon
Soy	78	30
Peanut	75	25
Cottonseed	73	41

1/ Based on 6 g. of homogenate, dehulled, defatted product.

Table 9.--*In vitro* gas production of various oilseed flours

Oilseed flour[1/]	Average gas volume, cc.		Gas composition,	
	6 hr.	24 hr.	$\%CO_2$	$\%H_2$
Soy	24	42	52	45
Peanut	26	42	42	67
Cottonseed	16	44	50	47

1/ Dehulled defatted sample of 0.5 g.

In vivo studies with isolated intestinal segments in dogs and *in vitro* assay with anaerobic cultures from the dog colon indicate that fermentation of carbohydrates is the primary cause of gas production. There is complete agreement between these studies and previously reported experiments with humans. The *in vitro* assay was used to follow extraction of the soybean flatulent factor and to detect flatus inhibitors. Ferulic acid and syringic acid will completely inhibit *in vivo* and *in vitro* gas production. Defatted cottonseed and peanut flours produce flatus in amount and composition comparable to dehulled defatted soybean meal.

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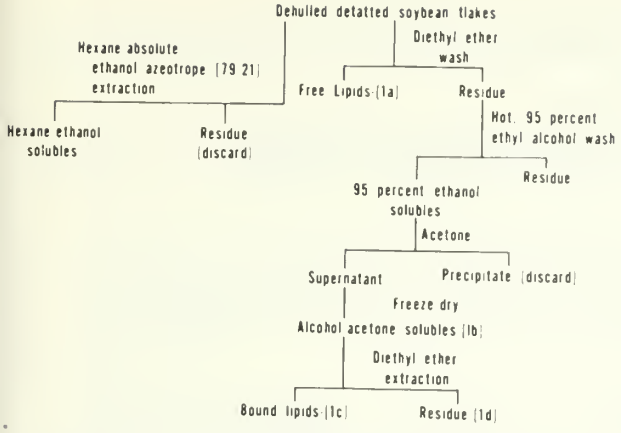

Figure 1. Extraction and fractionation of the flavor constituents of dehulled defatted soybean meal.

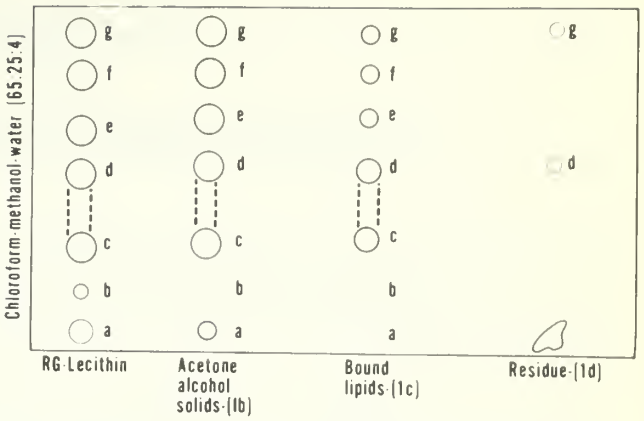

Figure 2. Thin-layer chromatographic patterns of soybean meal fractions. Developing solvent chloroform:methanol: water (65:25:4).

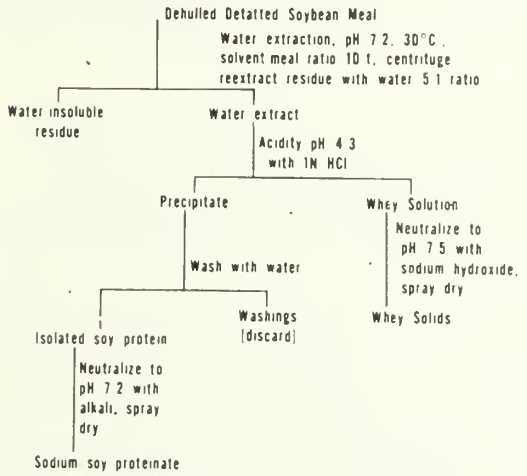
Dehulled Defatted Soybean Meal
Water extraction, pH 7 2, 30°C, solvent meal ratio 10 t, centrifuge reextract residue with water 5 1 ratio
Water insoluble residue
Water extract
Acidity pH 4 3 with 1N HCl
Precipitate
Whey Solution
Neutralize to pH 7 5 with sodium hydroxide, spray dry
Wash with water
Washings (discard)
Whey Solids
Isolated soy protein
Neutralize to pH 7 2 with alkali, spray dry
Sodium soy proteinate

Figure 3. Preparations of soybean meal products for flatulent tests.

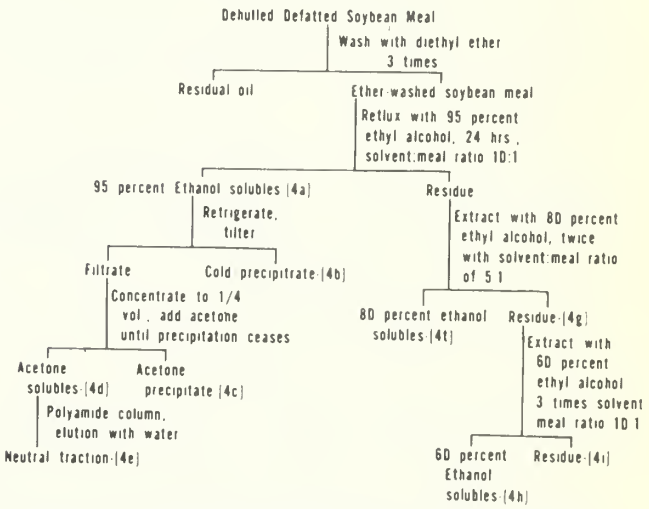
Dehulled Defatted Soybean Meal
Wash with diethyl ether 3 times
Residual oil
Ether-washed soybean meal
Reflux with 95 percent ethyl alcohol, 24 hrs, solvent:meal ratio 10:1
95 percent Ethanol solubles (4a)
Residue
Refrigerate, filter
Extract with 80 percent ethyl alcohol, twice with solvent:meal ratio of 5 1
Filtrate
Cold precipitrate-(4b)
Concentrate to 1/4 vol, add acetone until precipitation ceases
80 percent ethanol solubles-(4f)
Residue-(4g)
Acetone solubles-(4d)
Acetone precipitate (4c)
Extract with 60 percent ethyl alcohol 3 times solvent meal ratio 10 1
Polyamide column, elution with water
Neutral fraction-(4e)
60 percent Ethanol solubles-(4h)
Residue-(4i)

Figure 4. Aqueous ethanol extraction of the soybean flatulent factors.

TRYPSIN INHIBITORS, HEMAGGLUTININS, SAPONINS, AND ISOFLAVONES OF SOYBEANS

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The demand which the international shortage of food has created for cheaply produced and easily obtainable sources of all nutrients, and particularly of suitable proteins and fats, has directed attention anew to the possibilities of the soybean.

This modern-sounding statement is the opening sentence of a paper published almost 50 years ago by Osborne and Mendel (1) who provided much of the impetus for research on soybean constituents. Osborne and Mendel reported that rats grew poorly when fed raw soybean meal and that dry heat had no significant effect on the nutritional value of the meal. Cooking on a steam bath for 3 hours, however, yielded a meal which promoted normal growth of rats. They concluded that raw meal was not toxic since none of the rats eating it died. They suggested that cooking improved palatability of the meal, thereby making it more acceptable to the rats.

Fifty years later we find that Osborne and Mendel's moist heat treatment is still being used to improve the nutritive value of soybean meal. A clear-cut explanation of why such heat treatment is necessary is still lacking although a number of soybean components have been isolated and suggested to be antinutritional factors.

Soybean Protein Isolation. Before discussing four of the constituents often associated with poor nutritive value of unheated soybeans, it is desirable to discuss briefly the current method of processing defatted meal into isolated soybean protein (Fig. 1). Although a commercial procedure (2), this fractionation has also been useful in concentrating some of the antinutritional factors found in soybean meal (3,4). Isolated protein is prepared by extracting undenatured meal with water or dilute alkali to separate the proteins from insoluble polysaccharides. After removing the insoluble residue most of the proteins are recovered from the aqueous extract by adjusting the pH to the isoelectric point of the globulins where they are insoluble and hence precipitate. The protein curd is then washed and dried to yield the isoelectric form of the protein. Alternatively, the curd may be washed and neutralized with alkali before drying to obtain the proteinate form of the protein (5). Whey is the byproduct and contains a small amount of protein plus sugars, salts, and other low-molecular weight components.

Soybean Trypsin Inhibitors. Following its discovery in 1944 (6,7), trypsin inhibitor was one of the first components proposed as an antinutritional factor in soybeans. A year later, Kunitz (8) reported crystallization of

trypsin inhibitor. This protein has been characterized, and some of its physical and chemical properties are summarized in Table 1.

Table 1.--Physical and chemical properties of Kunitz' crystalline soybean trypsin inhibitor

Property	Item	Reference
Solubility	Globulin	(9)
Isoelectric point	4.5	(9)
Molecular weight	21,500	(10)
Amino acid residues	194	(10)
Amino terminal residue	Aspartic acid	(11)
Carboxyl terminal residue	Leucine	(11)
Cysteine residues/mole	0	(10)
Cystine residues/mole	2	(10,12)
Heat stability Reversible ⟶	irreversible denaturation	(9)

Although not soluble in water at its isoelectric point, trypsin inhibitor is soluble at pH 4.2 to 4.6 in soybean whey (Fig. 1) (4,13). Whey apparently contains sufficient salts to keep most of the inhibitor in solution. Some is also present in isolated proteins (14,15) and in protein concentrates prepared by dilute acid washing (13).

The crystalline inhibitor is a single polypeptide chain having a molecular weight of 21,500 made up of about 194 amino acid residues terminating in aspartic acid at the amino terminal residue and in leucine at the carboxyl terminal residue. It contains no sulfhydryl groups, but is crosslinked by two cystine disulfide bonds. Reduction of the two disulfide bonds inactivates the inhibitor, but activity is regained upon oxidation of the sulfhydryl groups to disulfide bonds (12).

Kunitz (9) showed that if trypsin inhibitor is heated at 90° C. for 2 minutes, it is completely inactivated but activity gradually returns on cooling. The extent of reversibility decreases as the time of heating is increased.

Although crystalline soybean trypsin inhibitor has been widely studied and assumed to be homogeneous, recent studies indicate that it is a mixture of proteins (10, 15-18). Polyacrylamide gel electrophoresis shows large variations among commercial preparations of the inhibitor; some preparations

consist of a major protein component, plus several minor components, whereas other preparations approach the complexity of soybean whey proteins (15).

An additional complication in elucidation of the role of trypsin inhibitor activity in soybeans is the occurrence of multiple forms of inhibitors. Three inhibitors, one of which was believed identical to Kunitz' inhibitor, were obtained by fractional precipitation with organic solvents (19). From four (20) to seven (21) inhibitor fractions have been separated from soybean whey proteins by diethylaminoethyl cellulose chromatography; one fraction had properties similar to crystalline inhibitor (20).

Several biological activities are attributed to trypsin inhibitor (Table 2). The literature on this subject is voluminous andoften controversial. With little or no knowledge of the other constituents present, investigators have sometimes attributed biological activities to trypsin inhibitor merely on the basis of experiments with soybean meal fractions enriched with inhibitor activity. Even use of crystalline preparations is no guarantee that observed effects are caused by trypsin inhibitor because of the complexity of many of these preparations (15-18).

The presence of proteins in soybeans which will inhibit trypsin in vitro is well established since Kunitz (22) was able to isolate a crystalline complex of trypsin and trypsin inhibitor. As soon as it was discovered, trypsin inhibitor was postulated to inhibit trypsin in vivo as a possible explanation for the poor nutritive value of raw soybeans. Although in vivo inhibition of trypsin may occur, it is now doubtful that this factor is significant in the inhibition of the growth of animals (30). Nevertheless, preparations of crystalline trypsin inhibitor will inhibit growth of rats (24, 25) and chicks (26).

Recent work has focused attention on the effects of trypsin inhibitor on the pancreas. In 1948, Chernick and coworkers (27) reported that chicks fed raw soybean meal had enlarged pancreases. It has since been shown that crystalline inhibitor causes hypertrophy in rats (24,25) as well as chicks (26). Hypertrophy in rats is reversible; rats on a hypertrophic diet for 38 days and then on a casein diet for 154 days had normal pancreases (31). Pancreatic hypertrophy may be peculiar to the growing animal. Chicks 12 weeks old before being placed on a hypertrophic diet showed minimal effects, and laying hens fed raw soybean meal for 8 weeks had normal pancreases (32).

An effect closely related to pancreatic hypertrophy, and perhaps the cause of it, is stimulation of the pancreas by trypsin inhibitor (25,28,29). Khayambashi and Lyman (25) fed rats with an amino acid mixture made up to simulate soybean protein with and without added trypsin inhibitor. Rats fed the inhibitor-containing diet grew less, had enlarged pancreases, had higher intestinal enzyme activities, and retained more undigested protein in the small intestine than control rats. Significantly, the undigested proteins

Table 2.--Biological properties of soybean trypsin inhibitor

Property	Reference
Inhibition of trypsin *in vitro*	(22)
Inhibition of trypsin *in vivo*	(23)
Growth inhibition	(24-26)
Pancreatic hypertrophy	(24-27)
Pancreatic stimulation	(25,28,29)

contained more essential amino acids and about 17 times more cystine than the undigested protein from the controls. Supplementing the diet with methionine, threonine, and valine prevented growth inhibition but did not prevent pancreatic hypertrophy or the intestinal changes observed in the absence of supplementation. These results support Lyman's earlier proposal (33) that trypsin inhibitor stimulates the pancreas to secrete excessive amounts of digestive enzymes, which are largely undigested and pass into the cecum and colon where they are lost to the animal through bacterial degradation and excretion in the feces. The high cystine content in the undigested enzymes presumably causes depletion of methionine by conversion to cystine to meet the requirements of the pancreas to synthesize the secreted enzymes. Depletion of methionine and possibly other essential amino acids by this mechanism is postulated to explain growth inhibition. Pancreatic hypertrophy is explained as a physiological response to continued stimulation by trypsin inhibitor.

In support of this mechanism, Barnes and Kwong (34) have shown that ingestion of crystalline trypsin inhibitor stimulated conversion of methionine-S^{35} into cystine-S^{35} in the pancreas of rats. Furthermore, radioactive cystine was subsequently found in the small intestine in high concentrations presumably in newly synthesized enzymes in response to the stimulus by the trypsin inhibitor. In the presence of penicillin, degradation of cystine by bacteria was reduced and a larger amount of cystine in the form of trypsin appeared in the feces. If the rat was permitted to ingest its feces, the cystine was recycled and apparently recovered. The rat normally ingests 35-50 percent of its feces (35), thus protection of the cystine during the first cycle may explain why penicillin improves the nutritive value of raw soybean meal (34).

While Lyman's proposed mechanism does not explain all the growth inhibition observed with raw meal (25), it does provide a valuable working hypothesis for further experiments.

From a practical standpoint trypsin inhibitors do not pose a serious problem in feeds and foods since they are readily inactivated by moist heat (24). Alternate methods of inactivating them may be desirable, however, in formulating foods where heat treatment causes undesirable changes in the functional properties of the proteins, such as decreased solubility.

Soybean Hemagglutinins. In 1951, Liener (36) reported that intraperitoneal injection of a crude trypsin inhibitor (soybean whey proteins) inhibited growth of rats and caused death when injected at elevated levels. Injection of Kunitz' crystalline trypsin inhibitor had no effect on growth. Subsequent work led to the isolation and characterization of soybean hemagglutinin (3,37), a protein distinctly different from soybean trypsin inhibitor. This discovery is an excellent example of the unsuspected complexity of soybean whey proteins. Further careful fractionation and biological testing of purified fractions may reveal other proteins that affect the nutritive value of raw soybeans.

The physical and chemical properties of soybean hemagglutinin are summarized in Table 3.

Table 3.--Physical and chemical properties of soybean hemagglutinin

Property	Item	Reference
Solubility	Albumin	(37)
Isoelectric point	6.1	(37)
$s_{20,w}$	6.4S	(37)
Molecular weight	89,000-105,000	(37)
Amino terminal residues/ mole	Two alanines	(38)
Carboxyl terminal residues/ mole	Serine and alanine	(38)
Mannose content	4.5 percent	(39)
Glucosamine content	1.0 percent	(39)

In contrast to crystalline trypsin inhibitor (Table 1) the hemagglutinin is an albumin, being soluble in water at its isoelectric point. It also has a higher isoelectric point than the inhibitor. Because of these two properties hemagglutinin occurs primarily in whey (13) after soybean meal is fractionated (Fig. 1). Other major differences between the two proteins are the higher molecular weight of the hemagglutinin, its multichain structure as indicated by the number of amino- and carboxyl-terminal residues,

and its content of mannose and glucosamine. Lis and coworkers (39) have confirmed the glycoprotein nature of hemagglutinin by digesting it with pronase and isolating a glycopeptide. The glycopeptide had a molecular weight of 4400-4600 and contained 24 mannose residues, 5 N-acetylglucosamine residues, and 1 aspartic acid residue.

In common with trypsin inhibitors, multiple forms of hemagglutinins nave also been isolated (4,21). Neither the significance nor origin of these multiple forms is as yet understood. The recent demonstration of protease activity in soybeans (40) suggests that proteolysis of parent trypsin inhibitor and hemagglutinin molecules during isolation procedures may be responsible for the multiple forms of the two proteins.

The biological properties of soybean hemagglutinins have not been studied in detail, but the known properties are listed in Table 4.

Table 4.--Biological properties of soybean hemagglutinin

Property	Reference
Agglutinates red blood cells *in vitro*	(41)
Toxic when injected intraperitoneally	(3,36)
Inhibits growth when fed to rats	(42)

The ability of hemagglutinin to cause clumping of red blood cells in a test tube proved to be the basis for a useful assay procedure (41), but it is doubtful that agglutination of red cells occurs when the hemagglutinin is eaten by animals or man. Since it is readily inactivated by pepsin (13,43), it probably does not survive digestion. Furthermore, undigested hemagglutinin would have to be absorbed from the intestine to come into contact with red blood cells, an occurrence which seems unlikely.

It is toxic when injected intraperitoneally into rats and chicks (36), but the mechanism of toxicity is unknown. Feeding purified heamgglutinin to rats at the 1-percent level indicated the hemagglutinin accounted for only about one-half of the growth inhibition observed with raw soybean meal (42). Growth inhibition, however, was accompanied by a decrease in food intake, which decline suggested a problem in palatability or an appetite depressant. Of interest is the earlier suggestion of Osborne and Mendel (1) that raw meal depresses growth because it is unpalatable to the rat and therefore consumed in smaller quantities than heated meal. Garlich and Nesheim (26) fed a crude hemagglutinin fraction to chicks and found no inhibition of growth.

The activity of the preparation used was 43 hemagglutinating units/mg., an amount which indicates a purity of less than 1 percent when compared to 5700 hemagglutinating units/mg. for purified hemagglutinin (39). Since an appreciable inactivation must have occurred during the isolation procedure, hemagglutinin may not have been present in the diet at high enough levels to exert a detectable effect.

Birk and Gertler (13) fed soybean whey proteins to rats on a heated soybean meal diet and observed only one-third of the growth inhibition experienced with raw soybean meal. Their conclusion that hemagglutinin is not an important factor in the growth inhibition of rats and chicks is, however, questionable. Although the whey proteins were added back to the heated soybean meal diet in an amount equivalent to that in raw meal, calculations show that the diet contained only 53 percent of the hemagglutinin content of the raw meal. Approximately one-half of the hemagglutinin activity of the raw meal was lost during fractionation.

Stead and others (21) separated soybean whey proteins into seven fractions by stepwise elution chromatography on diethylaminoethyl cellulose. Five fractions contained hemagglutinating activity, but only the one having the highest activity was toxic when injected intraperitoneally. A sixth fraction essentially devoid of hemaglutinin activity was also toxic when injected. These findings raise the question whether hemagglutination and toxicity are caused by a single protein.

Like trypsin inhibitor, hemagglutinating activity in soybean meal is readily inactivated by moist heat (41); consequently, it presents no special problems when meal is properly processed. Nonetheless, more information concerning its possible role in growth-inhibiting properties of raw meal is needed.

Soybean Saponins. Discussions of the antinutritional factors in soybeans often include saponins, but supporting evidence is rarely cited except for a brief, undocumented claim that soybean saponins inhibit growth of chicks (44). Recent studies by Bondi and coworkers in Israel now provide us with much new information concerning these compounds (45 to 50). Defatted soybean meal contains 0.6 percent saponins (50). These saponins are glycosides of five triterpenoid alcohols having the structures shown in Fig. 2 (46,51). Soyasapogenol E, which differs from soyasapogenol B by only two carbons, was discovered only recently (46). The sugars present in soybean saponins are galactose, glucose, rhamnose, xylose, arabinose, and glucuronic acid (49).

Physical and chemical properties of soybean saponins are listed in Table 5.

The crude saponin mixture obtained in 0.4 percent yield (48) from defatted soybean meal contains 24-27 percent carbohydrates (52), which give the saponins their polar character. They are soluble in water and in 80-percent ethanol, used to extract them from defatted meal (45). Soybean saponins are surface active; their aqueous solutions foam readily when shaken (45).

Table 5.--Physical and chemical properties of soybean saponins

Property	Reference
Carbohydrate content: 24-27 percent	(52)
Soluble in water	(45)
Soluble in 80 percent alcohol	(45)
Surface active	(45)
Heat stable	(45)

In contrast to trypsin inhibitors and nemagglutinins, the saponins in soybean meal are stable to autoclaving (45). The earlier suggestion that cooking of meal caused hydrolysis of saponins (44) appears incorrect.

Biological properties of soybean saponins are summarized in Table 6. Hemolysis of red blood cells serves as a useful tool for detecting soybean saponins (45) but apparently does not occur when soybean meal is ingested. Studies with rats, chicks, and mice demonstrated that the saponins pass through the stomach and the small intestine unhydrolyzed and without being absorbed (47).

Table 6.--Biological properties of soybean saponins

Property	Reference
Hemolysis of red blood cells *in vitro*	(45)
Inhibition of trypsin, chymotrypsin, papain, cholinesterase, and protease of *Tribolium castaneum*	(48)

Although they are hydrolyzed by bacterial enzymes in the lower digestive tract, they are not absorbed. Neither saponins nor sapogenins were detectable in blood of the test animals. Absorption of sapogenins in the upper digestive tract also needs to be investigated since hydrolysis of saponins may occur during processing of fermented foods.

At high concentrations soybean saponins will inhibit a number of enzymes (Table 6) but this interaction appears to be nonspecific and similar to that observed between proteins and other surface-active materials, such as detergents. The enzyme inhibitory effect can be overcome by casein and soybean proteins (48). Recent isolation of saponins from purified soybean globulins is supporting evidence of their ability to bind saponins (52).

Stability of soybean saponins to autoclaving raises the question of their possible role in growth inhibition by soybean diets. Gestetner and others (47) report no growth impairment of chicks, rats, or mice when soybean saponins were added to the diet.

It appears that we may be able to remove saponins from the list of anti-nutritional factors present in soybeans.

Soybean Isoflavones. Isoflavones, another group of compounds in soybeans, must be considered in assessing the nutritive value of soybean products. At present only two isoflavones are believed to occur in soybeans, genistein and daidzein (53,54). A third isoflavone, 6,7,4'-trihydroxyisoflavone, was recently isolated from tempeh, a fermented soybean food, but its occurrence in soybeans is still undetermined (55). The structures of the three isoflavones are shown in Fig. 3; the physical and chemical properties of genistein and daidzein are summarized in Table 7.

Table 7.--Physical and chemical properties of soybean isoflavones

Property	Reference
Yellow color	(53,56)
Phenolic in character	(53,56)
Glucosides	(53,56)
Insoluble in water	(53,56)
Soluble in alcohol	(53,56)
Ultraviolet absorption:	
λ_{max} 263 mμ (genistein)	(56,57)
λ_{max} 250 mμ (daidzein)	(57)
Heat stable (?)	(56)

The isoflavones are yellow compounds and their phenolic structure is distinctive. Like many phenolic compounds found in plants, they occur in

soybeans mainly as the glucosides, genistin and daidzin (Fig. 3). Small amounts of genistein, the aglycone, have been found in isolated soybean proteins (52) and in frozen tofu, a form of Japanese soybean curd (58). In contrast to the saponins, the isoflavones are relatively insoluble in water but are soluble in methanol and ethanol. Both isoflavones give characteristic spectra in the ultraviolet region, which are useful in their identification. Genistin has been isolated from commercial defatted soybean meal which presumably had been heated (56,59,60); hence, it is assumed that genistin is stable to autoclaving. However, drying of subterranean clover decreased its estrogenic activity (61) caused by genistein and other isoflavones. Likewise, drying Chana grain at room temperature resulted in loss of biochanin A (62) which is 4'-methyl genistein.

Of the two isoflavones in soybeans, genistein has been studied in greatest detail for its biological activities (Table 8).

Table 8.--Biological properties of genistein and genistin

Property	Reference
Estrogenic response:	
Increased uterine weight	(63)
Vaginal cornification	(64)
Infertility	(65)
Growth inhibition	(59,60)

Interest in the biological properties of isoflavones stems from the discovery in 1951 that genistein is estrogenic and that it causes infertility in sheep ingesting it by grazing on pastures of subterranean clover (66).

Although estrogenic, genistein has a low activity, it is reported to be only one-hundred-thousandth as active as the synthetic estrogen, diethylstilbestrol (63). Daidzein, the other isoflavone in soybeans, is only one-fourth as active as genistein (63). In spite of their low estrogenic activities, soybean isoflavones may have physiological effects because of their concentrations in soybean meal. Walz (53) reported 0.15 percent genistin and 0.007 percent daidzein, whereas Walter (56) found 0.1 percent genistin in defatted meal. Both estimates are based on yields of isolated isoflavones and are therefore likely to be low. Because genistein is present in higher concentration and has a higher estrogenic activity than daidzein, it is the isoflavone of greatest interest in soybeans.

Physiological effects of genistein and genistin isolated from soybean meal are reported (59,60,67,68), but little information is available about their effects when ingested at the levels occurring in meal and other soybean fractions. Carter and others (68) found commercial meal to be estrogenic when fed to mice; nearly a threefold increase in uterine weight occurred. Meal from which genistin was removed (presumably by alcohol extraction) was inactive. No details were given about the composition of the diet or the amount of diet consumed. The results, however, appear consistent with data of Wong and Flux (63) who found that mice receiving 5.9 mg. of genistein in 15 g. of diet over a period of 6 days showed a nearly twofold increase in uterine weight. If the diet of Carter and coworkers had contained 34 percent defatted soybean meal to supply 17 percent protein (minimum value estimated for diet used by Wong and Flux), the mice would have received 7.7 mg. of genistin or 4.8 mg. of genistein assuming 0.15 percent genistin in soybean meal. This level would be expected to give a significant increase in uterine weight.

Pieterse and Andrews (69) extracted soybean and cottonseed meals with 95 percent ethanol and incorporated the meal extractables into a ration at a level equivalent to feeding the meals as the sole source of the diet. Both meals gave positive estrogenic responses as measured by increase in uterine weights in mice. Data for feeding the alcoholic extracts at lower levels, however, were not reported.

Magee (60) fed rats a 19 percent casein diet containing 0.1 and 0.5 percent of genistin or genistein for 4 weeks. At the higher level the isoflavones decreased weight gain and decreased weights of the kidneys and spleens, whereas the lower level had no significant effect. Supplying the protein of this diet with 38 percent soybean meal (19 percent protein in the diet) would provide a dietary level of 0.06 percent genistin (assuming 0.15 percent genistin in the meal). Since this value is below the 0.1 percent level used by Magee, the genistin content of defatted soybean meal would not be expected to affect growth of rats.

Another factor to be considered regarding isoflavones in soybean products is their possible modification during processing. Pieterse and Andrews (69,70) found that moldy corn and alfalfa silage had increased estrogenic activities as a result of fermentation processes. They also found that refluxing genistein with 1.5 percent potassium hydroxide in 95-percent ethanol increased its estrogenic activity significantly. Occurrence of 6,7,4'-trihydroxyisoflavone in tempeh (55) may be an example of isoflavone modification during soybean processing.

Although no adverse effects concerning genistin and daidzin in soybeans under practical conditions are reported in the literature, more research is needed before deciding whether they are completely innocuous at the levels commonly

ingested. A method for quantitatively determining genistin and daidzin in soybeans is needed, and the possible presence of other isoflavones needs exploring. The distribution of the isoflavones in soybean products as a result of processing should also be determined. For example, soybean oil has a weak estrogenic activity (71), but the causative agent has not been identified. Genistein is soluble in peanut oil (68) and, therefore, may be the factor present in soybean oil.

Conclusions

Of the four soybean constituents reviewed here, trypsin inhibitors and hemagglutins are proteins and are readily inactivated by heat treatment. In contrast, soybean saponins are heat stable, but recent work has failed to show that they have any antinutritional effects. Isoflavones may also be heat stable, but no clear-cut statement can be made about their antinutritional effects because of insufficient information. In the past, interest in soybean isoflavones has centered primarily on animal feeds where no serious difficulties have been reported. With increasing use of soybean products in foods, the problem needs to be re-examined.

It should also be emphasized that much of our present information about these four soybean constituents is based on studies with defatted meal. As new processes are developed, it becomes necessary to re-establish optimum conditions for inactivation of the heat-labile components and to determine the content of the heat-stable factors. Conceivably, trypsin inhibitors and hemagglutins may be stabilized against heat inactivation and compounds, such as the isoflavones, may be concentrated under certain conditions of processing and fractionation.

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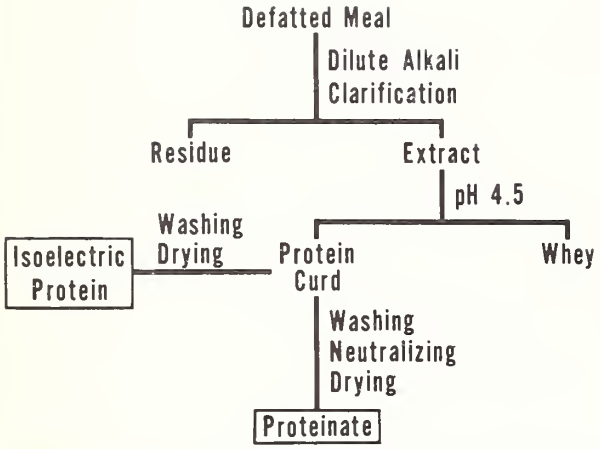


Figure 1. Commercial isolation of soybean proteins

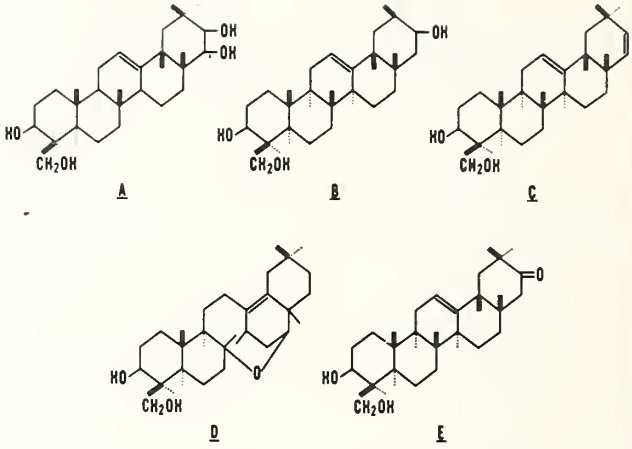
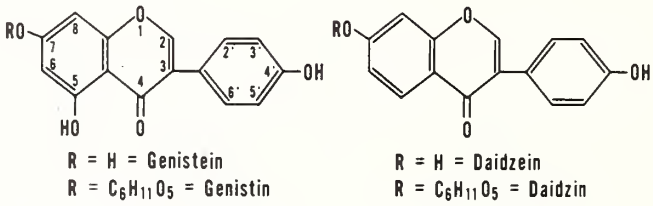


Figure 2. Structures of soyasapogenols



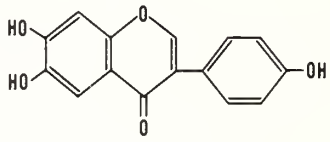


Figure 3. Structures of soybean isoflavones

SESSION III: MANUFACTURED SOY PRODUCTS

Harold L. Wilcke, Presiding
Vice-President and Director of Research
Ralston Purina Company, St. Louis, Missouri

DEFATTED AND FULL-FAT SOY FLOURS BY CONVENTIONAL PROCESSES

Francis E. Horan
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Minneapolis, Minnesota

The soybean is big business in the United States and in the world today. Here in the United States it can be regarded as the most outstanding phenomenon in agricultural crops thus far in the 20th century. Although soybeans were grown in the United States as early as 1804, they remained an agricultural curiosity and minor crop for over a century. In 1924, the total production was less than 5 million bushels but has grown rapidly, so that in the year just past (1965) the United States production totaled 844 million bushels. This year's crop should be somewhere between 900 and 925 million bushels. This amounts to about 70 percent of the total world production. The value of the 1965 crop was in the neighborhood of $2 billion. On the Chicago Board of Trade, soybeans have replaced wheat from the top of the future's market and now ranks in dollar trading as the country's leading agricultural commodity (1).

Of course, the value of the soybean, which contains about 18 percent fat and 35 percent protein, lies in the fact that there is a simultaneous high demand for both of these ingredients, either directly or indirectly, in human foods. The separation of these two major components of the soybean has given rise to the soybean processing or "crushing" industry.

The Soybean Processing Industry

The development of the soybean processing industry stems directly from World War I when such a shortage of fats and oils existed in the United States that it was necessary to import Manchurian-pressed soybean oil. After that War, fats and oils continued to be in great enough demand to make it seem worthwhile to try to crush domestic soybeans. Thus, it was that the origin of soybeans in American commerce was related to a demand for edible oil. At that time it was extremely difficult to get an adequate supply of soybeans

and just as difficult to dispose of the resulting soybean meal, which no one wanted to buy and few would accept as a gift. In fact, it was even difficult to sell the oil, because it was considered to be inferior to the imported product (2).

As is typical with the processing of most agricultural materials, markets must be obtained for more than one product. At times, it is merely academic to state that one product is the sole object of a process and that everything else is a byproduct. In the early history of soybean processing, it was seen that the production of oil was the prime objective. However, developments eventually arose which established soybean meal as the major source of protein used in feeding livestock and poultry. It is a bare economic fact that for a commercial process to be practical, markets must be found for all the products made, and that a rather delicate balance must always be maintained to prevent one product from becoming a glut on the market. The basic relationship in soybean processing is that 1 bushel of beans yields 11 pounds of oil and 47 pounds of residual meal. The 1965-66 domestic crush of soybeans was 538 million bushels, yielding approximately 5.8 billion pounds of oil and about 12.8 million tons of meal. Thus, of the 844 million bushels of beans harvested (plus 29 million carried over from previous crop), 538 million were processed, 257 million bushels were exported, 48 million bushels were used for seed and feed, leaving a carryover of 30 million bushels.

What about the markets for these large quantities of oil and meal? During the past 5 years the value of the meal has been about 60 percent of the value of the soybean products, while the oil provided about 40 percent. Thus, it is seen that the values are not disproportionately out of balance, and it is really not accurate to speak of one product as the prime one and the other a byproduct. The demand for the oil and meal has been increasing in recent years and appears to be strong during this present marketing year.

In addition to finding markets for oil and meal, other economic factors exert an important influence from the point of view of the processor. The factors very simply include the price paid by the processor for beans and his return on selling the oil and the meal in the commodity market.

To illustrate: In October 1963, processors paid $2.59 per bushel for soybeans; oil was selling at $0.0969 per pound and meal at $74.30 per ton ($0.0371 per pound).
1 bushel (60 pounds) yields 11 pounds of oil and 47 pounds of meal.

Oil income from a bushel equals	11 x 0.0969	= $1.07
Meal income from a bushel equals	47 x 0.0371	= $1.74
	TOTAL	$2.81
Margin per bushel (exclusive of processing)		= $0.22

However, in the latter part of March 1964, the processor paid $2.60 per bushel for soybeans, but the oil was selling at $0.079 per pound and meal at $0.032 per pound. This type of operation shows a loss of $0.23 per bushel (without processing costs) and indicates clearly the pitfalls for the soybean processor if marketing conditions are not favorable. Since the processor must live with the changing commodity prices of soybeans, oil and meal, there are indeed times when he has little control of the situation and must absorb his losses with the hope of better economic conditions at a later date.

One thing which he can do to improve his profit position is to develop specialty products, which he can sell at relatively fixed prices and stable processing costs. As far as edible products are concerned, not too much progress has been made along these lines with soybean oil but some encouraging steps have been taken with the introduction of soy flours and grits.

A reasonable estimate is that approximately 2 percent of the total meal produced today in the United States is in the form of edible soy flours and grits. Roughly this amounts to about 275,000 tons annually, compared with 12 million tons of soybean meal. Undoubtedly this type of production could be increased manyfold with existing facilities if the market demanded it. The trend appears to be an increasing use of soy flours in a variety of food products.

Definition and Composition of Soy Flours and Grits

Soy flour is defined as the screened, graded product obtained after expelling or extracting most of the oil from selected, sound, clean dehulled soybeans. However, a full-fat soy flour is not subjected to expelling or extraction and contains all of the oil originally present in the soybeans. The term "flour" generally signifies that the material has been ground finely enough to pass through a 100-mesh screen. Soy grits refer to particles of larger size and described in terms of the following U.S. standard screens:

Coarse	No. 10 to No. 20
Medium	No. 20 to No. 40
Fine	No. 40 to No. 80

The following general types of soy flour (or grits) are available commercially in the United States to meet specific needs (3):

1. Defatted soy flour is produced by nearly complete removal of the oil from the bean by extraction with hexane. There is less than 1 percent of residual fat (ether extract).

2. Low-fat soy flour is produced either as a result of partial removal of the oil or by adding soybean oil back to the defatted soy flour at a specified level, usually in the range of 5 to 6 percent.

3. High-fat soy flour is produced by adding soybean oil back to defatted soy flour at a specified level, usually in the range of 15 percent.

4. Full-fat soy flour contains all of the oil originally present in the raw soybeans, usually from 18 to 20 percent.

5. Lecithinated soy flour is a type of low-fat or high-fat flour in which lecithin is added to defatted soy flour at a specified level, usually in a range up to 15 percent.

The following average analyses are typical of some of the different types of soy flours and grits described above:

Composition of Soy Flours and Grits
("as-is" basis)

	Defatted percent	Low-fat percent	Full-fat percent
Protein (N x 6.25)	50.5	46.0	41.0
Fat (ether extract)	1.5	6.5	20.5
Fiber	3.2	3.0	2.8
Ash (minerals)	5.8	5.5	5.3
Carbohydrates (nitrogen-free extract)	34.2	34.0	25.2

The moisture content of soy flours and grits will vary from 5 percent to as much as 10 percent, depending on atmospheric conditions.

Of the approximately 30 percent of carbohydrates present, comparatively little has been known about the specific composition of this nutrient or its utilization as a source of energy in the body. However, a 3-year study of soybean sugars has recently been completed by Professor Kawamura of Kagama University (Japan) under a P.L. 480 grant by the U.S. Department of Agriculture (4). The results show that hexane-extracted soybean meal averages about 6.4 percent sucrose, 1.3 percent raffinose, and 4.5 percent stachyose. These sugars are the source of the toasted flavor acquired by soybean meal when it is processed for feed. The ash content is relatively high, and contains a fair amount of calcium. Soy flour and grits are a fairly good source of the B-group vitamins with a relatively high amount of thiamine.

Effect and Importance of Heat in the Processing of Soy Flours

It is well known that if a reasonably accurate knowledge of the amino acid content of a protein food is available, this permits an approximation of its nutritional value. The soy protein has a good balance with the limiting amino acid being methionine. However, it often occurs that a protein source

of excellent quality in the raw state, based on its content of the essential amino acids, may be markedly reduced in nutritional value as a result of the processing required to prepare it in a usable form.

When properly processed by means of moderate heating, the soybean protein has excellent nutritive value. Even though it is a well-established fact that both underheated and overheated soybean meals are of inferior nutritive value, comparatively little is known of the fundamental nature of the changes brought about in the protein as a result of the heating process.

Processing procedures in which time, temperature, and moisture are properly controlled are necessary in order to produce a soy protein product of maximum nutritional quality.

Various methods have been developed for in vitro testing of the efficiency of heat treatment received by soybean meal during processing. The two most commonly used today are the water-soluble protein--referred to in many ways, such as protein dispersible index (PDI)--and the urease activity.

Many years of processing experience now affords great reliability in using these practical tests as effective guides in controlling the nutritive value of soybean meal.

Typical commercial types available and their relative nutritional values are summarized below.

Commercial Types of Defatted Soy Flours

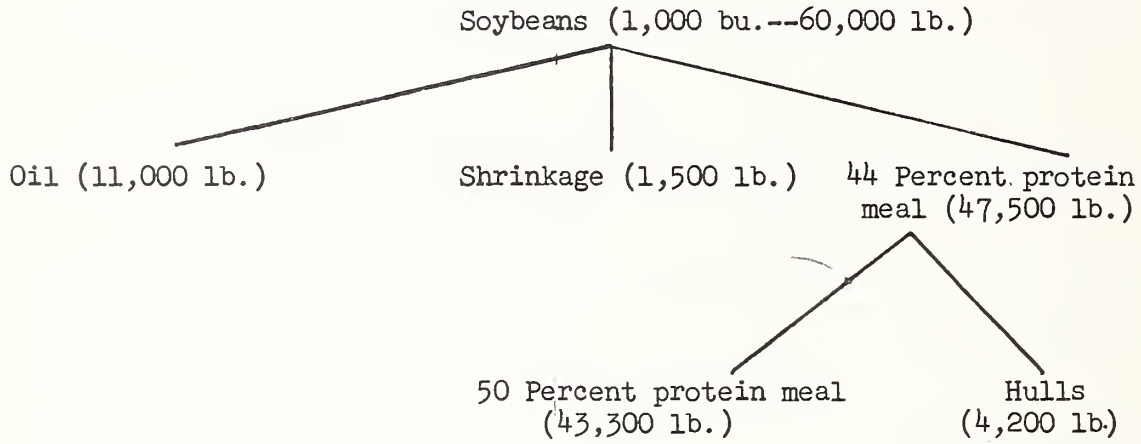
Type	Protein dispersible index	Relative protein efficiency[1]
Negligible heat	90-95	40-50
Light heat	70-80	50-60
Moderate heat	35-45	75-80
Toasted	8-20	85-90

[1] Dried skim milk equals 100 percent.

Methods of Applying Heat and Controlling Products

(1) Defatted Products

The soybeans are cleaned, cracked, dehulled, tempered, flaked, and extracted with hexane. The resulting flakes (50 percent protein) may be heat treated in a number of ways to give products with specific properties. The material balance may be represented as follows:


Soybeans (1,000 bu.--60,000 lb.)
Oil (11,000 lb.)
Shrinkage (1,500 lb.)
44 Percent protein meal (47,500 lb.)
50 Percent protein meal (43,300 lb.)
Hulls (4,200 lb.)

In some plants the hulls are removed before the oil extraction, and in others they are later separated by air classification from the 44 percent protein meal.

The wet flakes (containing approximately 30 percent hexane) are conveyed to the desolventizing or drying operations, of which there are three general types (5):

(a) Vertical, direct steam (desolventizer-toaster)
(b) Horizontal, steam jacketed (Schneckens)
(c) Recycled vapor (desolventizer-deodorizer-toaster)

(a) Desolventizer-toaster

The vertical-type desolventizer is a multiple-section vessel containing several pan sections in vertical arrangements. Direct steam is added at the bottom and proceeds upwards to drive off the solvent. The flakes are moving downward through openings in the pans. As they are rapidly heated with direct steam and agitated in the upper compartments, the moisture content of the flakes is increased up to 20 percent owing to steam condensation. Jacket

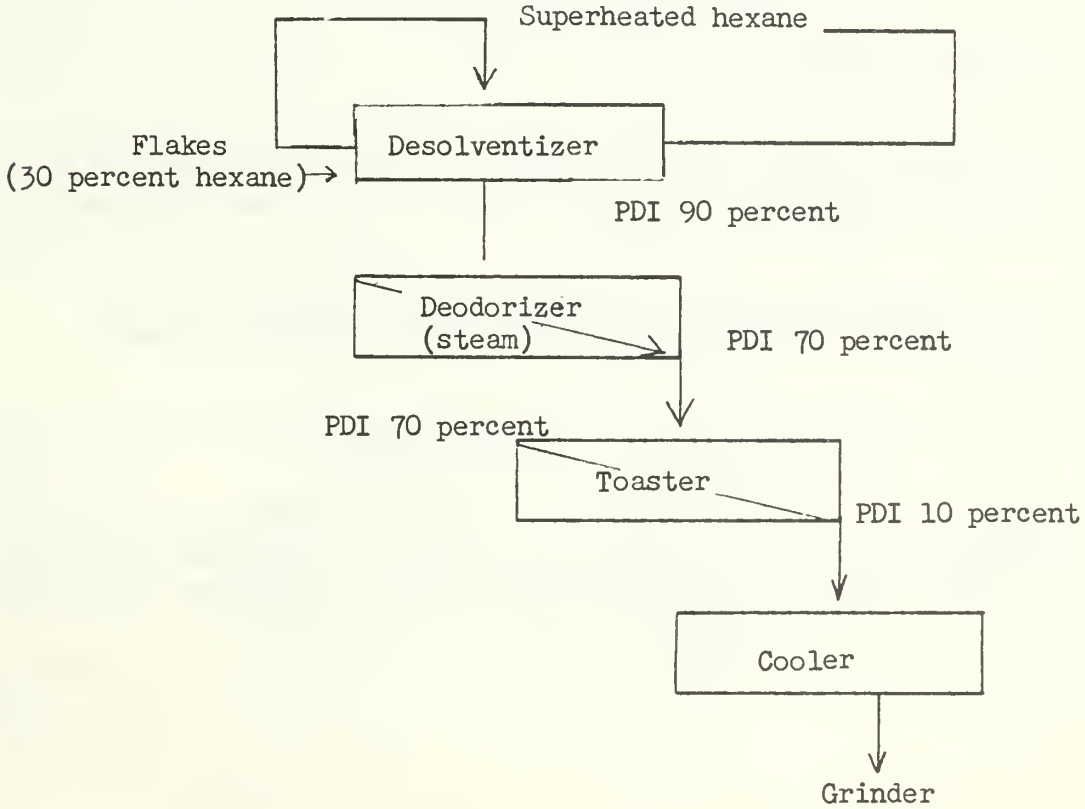
heat is ther applied, and toasting and drying proceed in the lower kettles of the unit where the temperature is increased from 220° F. to 230° F. The moisture content is reduced to about 13 percent before the meal is discharged into a cooler and before grinding. This method is a common one for the production of toasted meal for animal feeds, and the PDI ranges from 8 to 20 percent.

(b) Schneckens

This equipment has steam-jacketed paddle conveyers, usually arranged one above the other in banks of several units. The meal works its way down from top to bottom. Direct steam is usually introduced near the bottom outlet of the bank of dryers to displace the solvent vapor in the lower tubes. The PDI of this material is usually around 65 to 70 percent, and the flakes are ground to give an edible type of soy flour.

(c) Desolventizer-deodorizer-toaster

In this system the flakes are desolventized continuously by a rotating drum in which a part of the effluent vapors are superheated by an external heater and recirculated through the drum. The final solvent is stripped from the meal by live steam in a special section called a deodorizer. A schematic representation is given below.



This system has considerable versatility and permits commercial production of a variety of edible soy flours ranging from a practically uncooked type (PDI 90 percent) to a fully toasted product (PDI 10 percent).

(2) Fatted Products

In producing full-fat soy flour, clean, dehulled beans are treated first with live steam to deodorize and debitter them. Then the beans are dried to less than 5 percent moisture, passed through a cracking roll, and then ground to pass through a 200-mesh screen. The PDI of this type of product is usually 35 to 45 percent.

The dried, cracked, full-fat "meats" may also be processed in a screw-press to remove a major portion of the oil. The resulting cake contains about 6 percent fat and is sold in the form of grits or flour as a low-fat product.

(3) Bacteriological Properties of Soy Flours

As a matter of routine, bacteriological analyses are made on standard commercial soy flours and grits, because aqueous dispersions of soy flours are subject to bacterial attack. A bacteria count under 50,000 organisms per gram is considered good, and with proper processing conditions this specification is usually met. The low-fat and full-fat products have exceptionally low bacteria counts, as compared to defatted products, probably because they have had less moisture in their environment during processing.

Rope spores, which produce a "ropiness" in bread doughs, could create a serious problem if they were not controlled. Most producers of defatted flour recognize this potential hazard and have taken steps to keep this organism at a minimum.

Great strides have been made in improving conditions in soy flour production, and bacteriological contamination is steadily being eliminated.

Uses of Products With Different PDI's

Soy flours, which have had different types of heat treatment with corresponding different PDI values, find application in a variety of industries. The reasons for using one type of soy flour in preference to another are sometimes known only by the particular user involved.

Product type	Industry use
PDI 90-95	Bleaching agent in white bread
PDI 70-80	Bakery mix
	Doughnut mix
	Beverage
	Hydrolyzed vegetable protein
	Baby cereals
PDI 35-45	Pharmaceutical
	Baby cereals
	Meat processing
	Beverages
	HVP
	Bakery
	Pet foods
	Animal milk replacers
PDI 8-20	Pharmaceutical
	Baby cereals
	Bakery
	Meat processing
	Pet foods
	Animal milk replacers

Color, Odor, and Taste

A major stumbling block to the use of soy flours in the United States has been the presence of a "beany" odor and bitter taste. These disadvantages can be eliminated considerably by using a toasted product. However, toasting causes a darkening in color and oftentimes affects other properties, particularly when used in white bread. The introduction of a chemically treated soy flour (such as calcium chloride and hydrogen peroxide) offers improvement in this area, as illustrated in the following table.

Use of a Chemically Treated Soy Flour in White Bread (6)
(Used at the 5 percent level)

Type of test	Control (milk solids)	Ardex 550 (chemically treated)	Soy flour brand X
Loaf volume	830	925	767
External	Smooth, bold	Smooth, bold	Smooth, sl. flat
Crust color	Medium	Medium	Medium
Grain	Close, thin, elongated	V. sl. open, thin, elongated	Sl. thick
Texture	Velvety	Velvety	V. sl. harsh
Body	Strong	Strong	Med. strong
Crumb color	100	98	96
Odor	Normal	Normal	Sl. soy

This type of soy flour may be employed as a partial or complete replacement of milk solids in bread. An economic advantage for the soy flour to the baker exists, as is indicated in the following table.

Ingredient Cost[1] of 1,000 Loaves of Baked Bread (6)

Percent Ardex 550 (chemically treated)	Nonfat dried milk	Cost per 1,000 loaves	Savings per 1,000 loaves
--	3	$45.37	Base
0	2	45.02	$-0.35
1	1	44.54	-0.83
2	0	44.07	-1.30
1	2	44.90	-0.47
2	1	44.42	-0.95
3	0	43.95	-1.42
2	2	44.78	-0.59
3	3	45.28	-0.09

[1] All cases based on cost of ingredients delivered to Minneapolis.

Relationship of PDI to Functional Properties (7)

The PDI of soy flours may be decreased by heat or chemical treatments during processing. In addition to differences in the water-dispersible protein, certain functional changes also occur.

1. Wetting Properties

The consumers of soy flours have a definite interest in the wetting properties of these finely ground products. This is of major concern in the pre-blending of ingredients for large-scale operations. Laboratory tests show that there is a relationship between the PDI of a soy flour and its wettability, i.e., the lower the PDI the faster the rate of wetting. It does not appear to make any difference whether the specific PDI value is obtained by heating or by chemical treatment.

2. Foaming Properties

The degree of heat treatment during processing likewise affects the foaming characteristics of aqueous dispersions of the soy flours. The more the heat treatment, the less the foam. However, this correlation does not necessarily hold for chemically treated products. There are specific uses where a stable foam may be desired, such as in chocolate milk drinks, and therefore a specific soy flour might be selected.

3. Viscosity Properties

Soy flours with different PDI values also have different rheological properties when mixed with water. Farinograph curves using soy flours at 48 percent solids and 30° C. indicate that the apparent viscosity increases as the heat treatment is increased. Chemical treatment of the soy flours with certain salts, however, tends to stabilize the viscosity of the system as a kneading action is performed.

In studying the properties of soy flours in a visco-amylograph at 20 percent solids and using a heating and cooling cycle, it is learned that soy flours with different PDI values behave differently. The heat-treatment products show distinct viscosity differences upon cooling, whereas the viscosity of a chemically treated material changes relatively little during the heating and cooling cycle.

Baking Properties

In standard white bread baking tests, using nonfat dry milk solids as a control, it is known that a very lightly heat processed soy flour gives good results with respect to loaf volume, grain, and texture. However, it does contribute a characteristic strong odor, which is undesirable in United States bakeries. The chemically treated soy flours eliminate this odor problem, and thus are more suitable for use in breadmaking.

5. Water Absorption (8)

The addition of soy flour to semolina in the manufacture of macaroni-type products causes the finished product to retain its firmness much longer after cooking. This is related to a decrease in water absorption upon heating.

The Future

Soy flours today are used in a great variety of food products. One need only to study the labels of canned and packaged goods in a modern food supermarket to be made aware of this. An important feature of soy flours is their relatively low cost of unit protein.

Comparative Costs of Edible Protein Products

Protein product	Dollars per pound	Dollars per pound protein
Beef protein	0.75	4.20
Egg albumin	.75	0.85
Lactalbumin	.65	.82
Yeast	.30	.67
Casein	.55	.63
Milk solids	.16	.46
Isolated soy protein	.35	.40
Wheat gluten	.30	.38
70 Percent protein soy flour	.21	.30
Wheat germ	.08	.27
50 Percent protein soy flour (Ardex 550)	0.07	0.14

Several trends are appearing today in which vegetable proteins may soon be showing up in the form of finished textured food products. As one approach in this direction, recent developments in our company (ADM) indicate a promising commercial way in which soy flour can be upgraded into products adaptable for direct human consumption. These products are now being introduced under the descriptive name of Textured Vegetable Protein (TVP).

Essentially, TVP products are made by a special processing of soy flour to give a high-protein material, which is capable of carrying a variety of colors and flavors, and which retains its shape and chewable texture upon rehydration in water.

Some properties of TVP are:

(1) Meatlike appearance and eating characteristics
(2) 10 to 15 Minute hydration in simmering water
(3) Takes up about 2-3 times its weight upon rehydration
(4) Retains texture through thermal processing
(5) Varied sizes, shapes, and flavors
(6) Long storage stability in dry form
(7) Contains about 15 percent protein upon rehydration
(8) Can be used dry or rehydrated in thermally processed, refrigerated, or frozen foods

With these properties in mind, it is possible to let the imagination run far in thinking of innumerable food applications. Some of these might be snacks, condiments, casserole dishes, soups, camper's foods, pizzas, and combinations with bakery products, cheeses, and vegetables.

GPO 803-663-10

The direct human consumption of tasty soybean products in the United States is just beginning. It is also hoped that many of these products will eventually help to alleviate the hunger problems throughout the world.

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SOY PROTEIN CONCENTRATES AND ISOLATES

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Over the past 10 years, much attention has been focused on the commercial production and utilization of food-grade soy protein products. This ever-growing interest has been the result of a number of factors, among which can be mentioned the recognition of, and widespread concern for, the serious food protein shortages existing in many areas of the world, a better understanding of the technological function, and nutritional contribution of these protein products in food systems. During these same years, we have witnessed the commercial development and introduction of refined soy protein products designed for use in conventional processed foods and in totally new food items.

It is my objective to discuss the essential features of the commercial production of soy protein concentrates and isolates, to describe their composition and some of their properties, and finally, to review their current utilization in foods in relation to functional value with certain comments on nutritional contribution.

Soy protein concentrate has been defined as "the product prepared from high quality, sound, clean, dehulled soybeans by removing most of the oil and water-soluble nonprotein constituents and shall contain not less than 70 percent protein (N x 6.25) on a moisture-free basis" (1). It is interesting to note that products conforming to this definition were made a number of years ago for industrial usage as adhesives (2). However, it is only since 1959 that edible products of this type have become commercially available.

Soy protein concentrates are manufactured from hexane-defatted flakes or flour by three processes, which differ primarily in the means utilized to immobilize the major protein components during separation of the low molecular weight carbohydrates, mineral matter, and other minor constituents (Fig. 1). One process takes advantage of the fact that the protein components are insoluble in aqueous alcohol of about 60 to 80 percent concentration (3, 4, 5). Various solvent compositions and extraction temperatures can be employed and are chosen to give the minimal loss of protein compatible with an economical extraction rate of sugars and soluble matter. It is obvious that for economic reasons the organic solvent must be recovered and rectified in an efficient manner. Another process is based upon the long-known fact that the major soy globulins have limited solubility in aqueous acid at their average isoelectric point of about pH 4.5 (2, 6, 7). In this process, there is a greater loss of protein nitrogen because of the solubility of the "whey" proteins at this pH. In a third process, the proteins of the soybean source material are denatured by moist-heat treatment to insolubilize the proteins. The sugars and other constituents are then extracted with water (8).

All three processes are amenable to batch or continuous extraction operations. After drainage of solvent, the residual material is desolventized and dried. The product prepared by aqueous acid leaching may be neutralized with food-grade alkali prior to drying. Drying may be accomplished in various ways, using for example, range driers, Schnecken driers, flash driers, or spray driers. The last type is most often used with the neutral product arising from the aqueous acid leaching process. The yield of dried concentrate from each process is about 60-70 percent, based on the weight of defatted soybean flakes or flour.

Since the recovery of solvent is mandatory in alcohol-solvent processing, the solubles are concentrated sufficiently to permit their economical recovery in the form of a molasseslike sirup or in a dry state. This product contains, primarily, the sugars, sucrose, stachyose, and raffinose, together with minor sugars, nitrogenous constituents, and mineral matter, and can be used as an additive in feedstuffs. With aqueous processing, the soluble solids can also be recovered by evaporative means.

As is true of all food and food ingredient processing, the sanitation aspects of process and equipment design for the production of soy protein concentrate must be given serious consideration. The alcohol process has an advantage in that the solvent employed is not conducive to microbial growth.

The commercial soy protein concentrates derived from the three basic processes have the same gross compositional characteristics (Table 1). The residual polysaccharides in the concentrate consist mainly of arabinogalactan and acidic pectin-type polysaccharide together with some galactomannan, xylan hemicellulose, and cellulose arising from the soybean hull. The crude fiber content is indicative of the efficiency of the dehulling operation in preparing the defatted source material. The concentrates prepared by the aqueous alcohol and the water extraction processes have low nitrogen solubility indices because of protein denaturation by the solvent in the former instance, and through moist heat in the latter. In contrast, the product of aqueous acid extraction, when neutralized before drying shows a higher nitrogen solubility index. The essential amino acid compositions of the three commercial concentrates are also about the same; some minor differences may arise from varietal differences in the bean and in the nature of the nitrogenous substances removed through extraction (Table 2).

Soy protein concentrates have a low flavor level and range in color from cream-yellow to light tan. High nitrogen solubility is retained in the concentrate prepared by aqueous acid leaching followed by neutralization. All soy protein concentrates possess water absorption and fat-binding characteristics, functional properties of value in various food systems. The low flavor level, together with improved absorption characteristics as compared to commercial soy flours, have been major factors in the acceptance of soy protein concentrates for food use.

Table 1.--Percentage composition of soy protein concentrates

Item	A	B	C
Moisture	6.7	5.2	3.1
Protein (N x 6.25)	66.2	67.3	69.6
Protein, m.f.b.	70.9	71.1	72.2
Fat (petr. ether)	0.3	0.3	1.2
Crude fiber	3.5	3.4	4.4
Ash	5.6	4.8	3.7
Nitrogen solubility index	5	69	3
pH (1:10 aq. disp.)	6.9	6.6	6.9

Table 2.--Amino acid composition of soy protein concentrates

Essential amino acids, g./16 g. N[1]	A	B	C
Lysine	6.6	6.2	6.2
Methionine	1.3	1.4	1.4
Cystine[2]	1.6	1.6	1.5
Tryptophan[3]	1.4		
Threonine	4.3	4.4	4.2
Isoleucine	4.9	5.0	4.9
Leucine	8.0	8.3	8.1
Phenylalanine	5.3	5.6	5.3
Valine	5.0	5.1	5.1

[1] Ion-exchange chromatography.

[2] Determined as cysteic acid--Schram and others.

[3] Colorimetric method--Spies and Chambers.

Another advance in soybean food technology is the commercial isolation of the major protein component, often referred to as the acid-precipitable fraction (9, 10). Basically, the isolation of the protein fraction of the soybean is not a new concept since this was practiced, in modified form, in the ancient Orient, and indeed, today. Large-scale factory production of a soy protein isolate in the United States dates from 1937 and was, and still is, concerned with the manufacture of modified products suitable for adhesive purposes in paper coating applications. The first commercial-scale plant for the production of edible grades of soy protein isolate went into operation in the United States in 1959. Since that date the production capacity for the food-grade products has been expanded by several companies.

Although large quantities of both the edible and industrial grades of soy protein isolate are produced in this country, there exists little published information with respect to the specifics of design, equipment, and operation of processing plants. This is understandable because the large-scale commercial know-how is limited to a few industrial organizations. Nonetheless, the general principles of process and product chemistry are fairly well documented.

The isolate is prepared from defatted soybean flakes or flour, which has had minimal exposure to moist heat in order to retain maximum protein dispersibility (Fig. 2). The protein is extracted with an aqueous medium which may vary in pH from near neutrality to an alkaline pH. The important variables such as liquid-solids ratio, pH, time, and temperature are selected to obtain optimally economic, and not necessarily maximum yields. The aqueous extract is separated from the fibrous residue by various screening, filtering, and centrifuging devices. The pH of the clarified extract is then adjusted to about pH 4.5 with food-grade acid to precipitate the major globulin proteins. The protein curd is concentrated and washed with water by various means such as filtering, centrifuging, and combinations thereof. In most instances the protein is concentrated to a slurry or cake containing 15 to 30 percent solids.

The concentrated protein can be either dried as such, or neutralized with food-grade alkali and dried. Much of the edible protein is sold in the neutral or sodium proteinate form since this product is water-dispersible, and hence lends itself to ready incorporation in food-products systems for maximal functional value. Potassium and calcium proteinates have been offered for sale. Although drum or roller driers have been employed, spray driers are most often used for the drying operation.

In order to ensure that the product meets food-grade standards, major attention must be given to process and equipment design and sanitation control. A food quality isolate must meet acceptable bacteriological standards.

The literature references show the yield of soy protein isolate to vary considerably. One pilot-plant study indicated yields of about 33 to 43

percent, based on flake or flour weight, depending upon the variety of soybeans used (11). Another study showed that the yield of protein, as obtained under ideal laboratory conditions, was about 42 percent of the defatted flake weight; however, it was stated that 30 percent was good for commercial operation (12). The yield is directly dependent on the protein content of the source material (13), the extent of protein denaturation in the production of the source material, the extraction conditions, and the efficiency of the various unit processes. The economics of the operation are considerably influenced by the ability to dispose of both soluble and insoluble byproducts.

Table 3.--Proximate analyses of commercial soy protein isolates

	A	B	C	D
Moisture, percent	4.7	6.4	7.6	3.7
Protein (N x 6.25), percent	92.8	92.2	92.9	94.7
Protein, m.f.b., percent	97.4	98.7	100.0	98.4
Crude fiber, percent	0.2	0.1	0.1	0.2
Ash, percent	3.8	3.5	2.0	2.7
Nitrogen solubility index, percent	85	95	--	--
pH (1:10 aq. disp.)	7.1	6.8	5.2	5.5

The proximate analyses of several samples of commercial soy protein isolates from several sources are given in Table 3. It should be noted that these products are of good commercial quality with low residual fiber contents. Samples A and B are sodium proteinates and, hence are water-dispersible; whereas samples C and D represent the "isoelectric" form which has a lower pH, lower ash, and is nondispersible in water. When properly processed, the soy protein isolates are light in color and possess a low flavor and odor level.

The essential amino acid compositions of the commercial soy protein isolates are given in Table 4. The isolates, as a rule, are lower in the critical sulfur amino acids than either the concentrates or the soy flours. Differences are noted, which may be ascribed to source material and processing conditions. Actually, there is need for more information on the amino acid composition of the major globulin or acid-precipitable fraction derived from soybeans of different varieties. This could be important in improving the nutritional value of the isolate.

Table 4.--Amino acid composition of soy protein isolates

Essential amino acids, g./16 g. N[1]	A	B	C
Lysine	6.0	6.0	5.8
Methionine	1.2	1.0	1.0
Cystine[2]	1.2	0.9	0.9
Tryptophan[3]	--	1.3	1.3
Threonine	3.6	3.7	3.8
Isoleucine	4.6	4.9	4.8
Leucine	7.7	8.1	7.8
Phenylalanine	5.2	5.6	5.5
Valine	4.6	5.0	4.6

[1] Ion-exchange chromatography

[2] Determined as cysteic acid--Schram and others.

[3] Colorimetric method--Spies and Chambers.

A number of past reviews have described the various physical and chemical properties of soy protein isolate which can be of significance in the design of foods from a functional standpoint (9, 14, 15). These include properties such as dispersing, suspending, gelling, thickening, emulsifying, fiber-forming, and fat- and water-binding among others. A number of workers have made excellent contributions to our knowledge of the basic chemistry of the heterogeneous soy globulins. Yet this effort needs to be continued and expanded in an effort to shed more light on their behaviorism in food systems, particularly in relation to changes and interactions during processing.

We have been interested in the heat gelation phenomenon of soy protein isolates because of its value in attaining structure and texture for certain classes of recognized food items (16, 17, 18). Earlier work has demonstrated that gel formation is a heat-activated irreversible process, which is concentration, pH, and temperature dependent. At a critical temperature, the gel can be disrupted. More recent work has indicated to us that there exists a progel state which is reversible with the gel state below the critical temperature (Fig. 3). We have called the state existing after disruption of the gel the metasol state. Proteins of this general nature can also be achieved through the action of chemical reagents such as alkalies at high pH, sodium sulfite, which cleaves disulfide bonds, and enzymes. I

don't mean to imply that all proteins in the metasol state are the same in that identical reactions are involved in the transformation to this state. But in the design of certain foods it can be important to know whether the protein forms a sol or metasol; whether it gels. I cite this solely as an example of the type of information which should prove of value to the food technologist in utilizing and controlling the functional qualities of soy protein isolates in the preparation of foods having a variety of physically desirable forms.

There are a number of published accounts which list many potential food uses for both soy protein concentrates and isolates (9, 14, 15). Certainly many of these uses hold much promise for future development. However, I prefer to restrict my brief discussion to known current commercial uses and to certain commercial developments which can come to fruition within the next few years. I will not include meat analogues since Dr. Odell will cover this subject at the next session of this Conference.

The major current food uses of soy protein concentrates are listed in Table 5, and those of soy protein isolates are listed in Table 6. With certain obvious exceptions such as infant formulations, dietary wafers, breakfast cereals, and special dietary items, these soy protein products are now being used, primarily, for their functional characteristics. These characteristics are important to the manufacturer of conventional food items in processing control, in the improvement of product quality, in product economy, and in the design of new convenience foods.

The largest single area of current food utilization is in certain processed comminuted meat products, particularly sausage and related cured meat items (15, 19, 20). Because of the variability of certain meats in producing cooked sausage having manufacturing tolerance and consumer acceptability, there has been established in sausage production a recognized place for binding agents; which, when used in minor amounts, supply good moisture-holding and fat-dispersion qualities. Both soy protein concentrate and isolate have found a place in sausage production. Isolated soy protein, because of its fat emulsifying and dispersing properties, and its ability to form structural elements on heating, has proven particularly useful in sausage and in canned meat products, which are subjected to the stress of high temperature processing. Although this is a growing field of use, one can project for the future the commercial development of meat-containing products which have a high soy protein content and retain all the desirable textural and flavor properties and acceptability associated with products of this

A newer food field--one which will be dominated by the soy protein isolates --is that of the so-called dairy-type products (9). This class is exemplified by coffee whiteners, whipped toppings, and frozen desserts, and can eventually encompass dips and spreads of a cheeselike nature. In these instances the protein functions as an emulsifying and emulsion-stabilizing agent.

Table 5.--Food uses of soy protein concentrates

Comminuted meat products
Sausage
Luncheon loaves
Patties
Chili con carne
Breading
Breakfast cereal
Dietary wafers

Table 6.--Food uses of soy protein isolates

Comminuted meat products
Frankfurters
Bologna
Miscellaneous sausage
Luncheon loaves
Canned luncheon loaves
Poultry products
Dairy-type products
Coffee whiteners
Whipped toppings
Frozen dessert
Beverage powder
Dried soup mixes
Infant formulations
Special dietary items

Another type of product that is finding a place in prepared convenience foods are meat bits derived from cooked meat tissue and soy protein isolate (21). It is claimed that incorporation of the isolate improves the dehydration and rehydration characteristics of the cooked meat bits.

There are certain selected food items wherein these soy protein products are used principally for their nutritional value. On the other hand, I have illustrated that many more current uses of soy protein products may be ascribed to their functional properties in food systems. Admittedly, this division is not a clear one since nutritional properties cannot be divorced from processed food design. It is recognized that food having good nutritional value must be presented in forms having consumer-acceptable structure and flavor patterns.

Because of the potential of soy protein products in providing useful food protein to fill an ever-expanding need, the nutritional properties of both soy protein concentrates and soy protein isolates have continued to receive attention (22, 23, 24). In Table 7, I have summarized data on the weight gains and protein efficiency ratios obtained from rat feeding studies on three commercial soy protein concentrates believed to represent the products of the three processes described earlier. All products show good PER values. In 1964, Longenecker, Martin, and Sarett reported that soy protein concentrates were considerably improved in nutritional value on moist heating (25). We have not been able to demonstrate these findings in recent work on commercial soy protein concentrates. In contrast to the earlier products, perhaps the current products have been more completely processed to remove or destroy inhibitory substances. As in all soy protein products, the sulfur amino acids, particularly methionine, are limiting. Supplementation with methionine results in a significant increase in nutritional value as measured by weight gains and PER values in rats.

Further nutritional data are reported in Table 8. In general, the commercial soy protein isolates have shown variable and lower nutritional responses in rats than the soy protein concentrates. The variation in response of commercial isolates may reflect, in part, certain variations in methionine and cystine contents as influenced by source material and processing conditions, and completeness of removal of soluble inhibitory substances after acid precipitation of the globulin fraction. As demonstrated with soy protein concentrates, the isolates are considerably improved in nutritional quality by supplementation with methionine; and, indeed, newly introduced hypoallergenic infant formulations are based on soy protein isolate supplemented with DL-methionine.

In assessing the nutritional contribution of soy protein products in processed foods containing other protein sources, it is necessary to consider the value of the composite protein. Because of our interest in meat products, we have evaluated comminuted meat-isolated soy protein mixtures ranging up to 25 percent protein from the soybean source--the remainder made up of meat protein.

Table 7.--Soy protein concentrates--protein quality

Rat feeding studies: 10 percent protein in diet, 4-week period

Commercial concentrate	Weight gain, g.	PER	Corrected PER[1]
A	98	2.43	2.29
B	92	2.29	2.16
C	106	2.50	2.36
Concentrate + 0.15 percent DL-met.			
A	131	3.18	3.00
B	131	3.05	2.88
C	133	3.24	3.06

[1] PER corrected to a casein value of 2.50; actual value--2.65.

Table 8.--Nutritional value of soy protein products

Rat feeding studies: 10 percent protein in diet, 4-week period

Product	Protein efficiency ratio (range)
Soy protein concentrate	2.02-2.48
+ 1.5 percent met.	3.09-3.24
Isolated soy protein	1.08-2.11
+ 1.5 percent met.	2.11-2.45

Source: Various.

This work is summarized in Fig. 4. Up to the 25 percent level, there proved to be no significant reduction in PER. Several studies on white bread supplemented with isolated soy protein have indicated that improved protein value can result from the combined protein source (26, 27). In addition, Wilding, McGinnis, Alden, and Rice reported on the supplemental value of soy protein concentrate and wheat proteins in bread, showing a significant increase in both weight gains and PER's in rats (28). It is obvious that erroneous conclusions can be drawn from the examination of a protein as a sole source of food protein at a restricted level when this protein is to be used in conjunction with other food proteins.

In closing, I want to comment on current pricing and estimated sales volumes of soy protein concentrates and soy protein isolates, and then to make some rough projections on pricing in the near future. At present, the soy protein concentrates sell for 18 to 28 cents per pound; the isolates sell for about 35 to 38 cents per pound. In presenting the estimates of current sales volume, I wish to emphasize that these figures are really "guesstimates," because such data are not available. Nonetheless, it is my opinion that the soy protein concentrates are now selling at a level approaching 15 million pounds per year, and the isolates at a level of about 10 million pounds per year. This past spring, Central Soya announced the construction of a plant for soy protein isolates having a 30 million pound per year capacity. With continuing technological improvements, the price of soy protein concentrate may drop to 14 cents per pound over the next 5-year period. During the same period, it may be predicted that the price of soy protein isolate may decrease to about 28 cents per pound. Necessarily, such price decreases can come about only through increase in the volume of usage and through process and product improvements.

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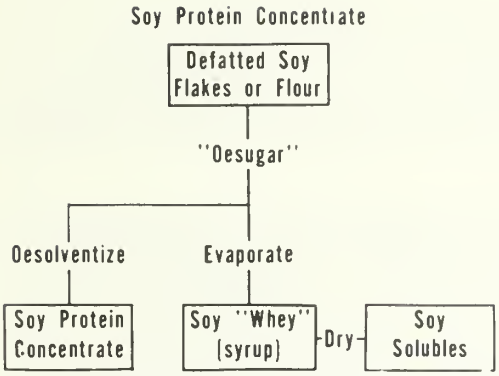

Figure 1. Production of soy protein concentrate

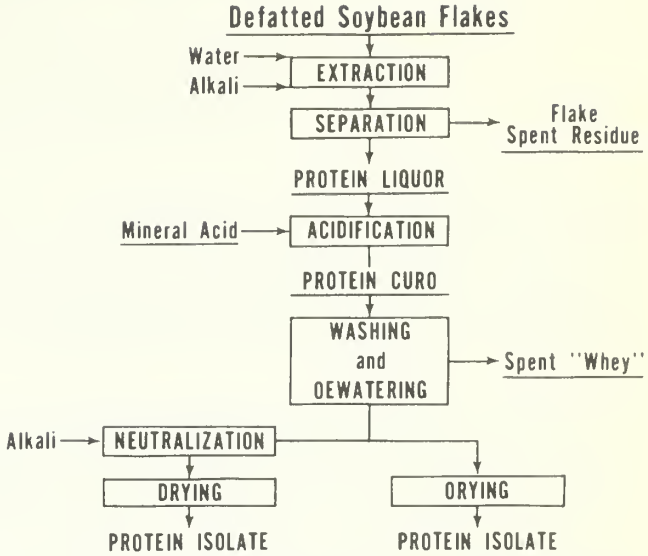

Figure 2. Production of soy protein isolate

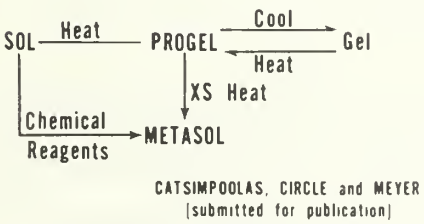

Figure 3. Transitions of isolated soy protein dispersions

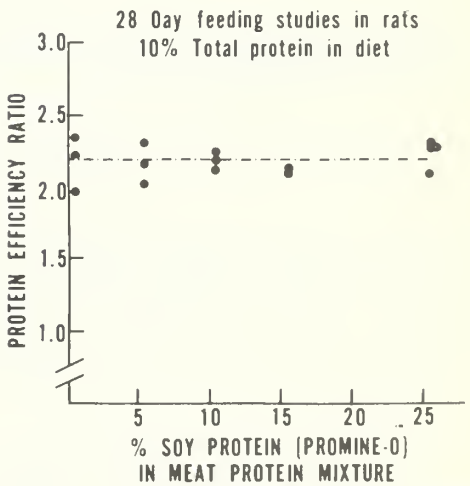

Figure 4 Nutritional value of meat protein-soy protein mixtures

ALTERNATIVE PROCESSES FOR FULL-FAT SOY FLOURS FOR USE IN DEVELOPING COUNTRIES

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The food shortage among the developing nations has intensified efforts to develop low-cost protein foods based on crops that can be grown in these countries. Under discussion at this Conference is the need for protein in weanling infants and preschool children. Soybean protein contains a good balance of the amino acids essential to human nutrition and, in this regard, is nearly comparable to animal protein.

Recently, USDA's Agricultural Research Service, in cooperation with AID, launched a program that includes studies to improve the processing of soybeans for foods. Our part in this program is research on converting soybeans to a full-fat soy flour. Such a flour includes all the nutritive value of the soybean with only the hull removed. Antinutritional factors, however, must first be destroyed by processing. The flour can then be used as a high-protein supplement for baby formulations and in many other foods for the newly developing nations.

Alternative processes for making full-fat soy flour either by simple hand procedures or by mechanical extrusion cooking are being developed by the Northern Laboratory.

The Cottage-Type Process

One phase of this research is to devise a simple hand process for villages in foreign lands where skilled labor, electric power, and steam are not available. Both equipment and fuel, therefore, must be within their means.

We investigated several basic and simple methods for cooking soybeans:

(1) Atmospheric steaming
(2) Water-immersion cooking
(3) Various forms of dry heating or roasting

We wanted to (1) inactivate growth inhibitors, (2) produce a bland and palatable product, and (3) obtain a flour with good storage stability.

Early studies showed that initial moisture was a highly significant factor in cooking rate. Overnight-soaked beans, which reached moisture contents of 62-68 percent, cooked rapidly. Cracking the beans was not necessary to achieve a rapid cooking rate. Figure 1 shows the effect of initial moisture on cooking rate when steaming whole beans at 100° C.

GPO 803-663-11

Of the methods tried, water immersion looked the best for rapid cooking and simple control. This method yielded a nutritive product and could be adapted to hand operation by untrained people. Figure 2 shows the decrease of urease activity and nitrogen solubility index (NSI) with immersion time of the beans in boiling water.

Figure 3 is a flowsheet of the process that was developed.

The hand-operated equipment used in our studies is photographed in Figures 4 to 9.

A typical composition of the experimental soy flour is given in Fig. 10. Available lysine ranging from 6 to 6.5 indicates good nutritive value. Rat bioassays are now in progress to evaluate the protein completely.

The experimental flour is also being tested in many basic food formulas and food combinations in cooperation with the Human Nutrition Research Division, ARS, USDA, at Beltsville. The flour has good flavor acceptability and stability. Some types of foods being prepared at Beltsville include soy beverages for babies and young children, yeast breads, main dishes, cereal products, and baked desserts. Objectives in these preparations are to use the optimum amount of soy flour to gain a nutritious product, to provide a palatable product, and to make foods which resemble those indigenous to various developing countries.

Adapting the simple flour process to an emerging country should not be difficult. We believe that it is nearly ready for trial outside the United States. However, I should point out that environmental conditions in a specified country could necessitate some alterations in procedure. For example, drying soybeans in an area of high humidity might require selection of proper atmospheric conditions or even a modified drying method.

Equipment is simple. Moreover, it can be readily modified from hand to mechanical operation by wind, water, or animal power depending on the ingenuity of people. It is low in cost. Total cost of the production unit is estimated to be $250 or less. With this equipment, 6 men can produce 300 pounds of soy flour in an 8-hour day. These 300 pounds will supply half the daily requirement of protein for more than 1,600 adults.

The Extrusion-Cooking Process

Extrusion processing, a method continuing to find new and wider applications in the food industry, is adaptable to the production of full-fat soy flour, and can produce an edible flour of good flavor, oxidative stability, and high nutritional value. Basic machinery for the process is now in use and is widely available for food manufacturing. To accomplish soybean cooking, a

single screw housed in a close-fitting cylinder rotates at high speeds to produce heat and pressure. Thus, the soybean extruder acts as a continuous pressure cooker to compress, cook, and discharge meal through a narrow die restriction. After being cooked, the meal is dried, cooled, and ground to flour.

Extrusion equipment was tested in 1961 by the Wenger Company, Sabetha, Kansas, to convert soybeans directly to full-fat meals for animal feeds. In swine feeding tests carried out on these meals at Lafayette, Indiana, Purdue University reported high weight gains and good feed conversion. It appeared to us that with some modification, including dehulling, a similar process could be developed to produce an edible-grade full-fat soybean product for human foods.

In 1962-63, a cooperative project to investigate the extrusion process was undertaken by the Northern Laboratory with UNICEF and the Wenger Company.

A flowsheet of the extrusion process is shown in Fig. 11. Soybeans are cracked, dehulled, and flaked on rolls. Flakes going to the storage bin contain about 9 to 10 percent moisture. They are then preconditioned with open steam injected to add water and heat. Next, they are mixed to ensure uniformity before going through the cooker-extruder. Moisture content increases to about 20 percent in the preconditioner and the mixer. The product from the cooker-extruder is dried, cooled, and milled to the desired degree of fineness.

The short cooking time in the extrusion process minimizes damage to nutritional properties but still adequately removes growth inhibitors. This removal was indicated by low assays for trypsin inhibitor and urease activity.

Composition of the flour is given in Fig. 12, although the percentages do not add up to 100 since the carbohydrates present are not indicated. The carbohydrates include sucrose, stachyose, raffinose, pentosans, and galactans.

In organoleptic evaluations at our Laboratory, the extrusion-cooked flours scored relatively high in blandness of flavor; they compared most favorably with a commercial soybean flour. Accelerated storage tests were conducted at 100° and 113° F. up to 9 months. At the higher temperature, good stability was exhibited through the first 9 weeks. At 100° F. good stability was maintained throughout the entire 9-month period as determined by odor, taste, free fatty acid, and peroxide value test. Extrapolation of these data by previous experience to 70° F. storage indicates that the extruded flour should have good stability for 1-2 years.

The results of protein efficiency ratio (PER) tests in rat feeding indicate that the experimentally extruded products are of high value and are at least equal to commercial soy flours.

Feeding tests with broiler chicks at the University of Maryland showed that for growth promotion and efficiency of feed conversion, the extruded product was equal to good quality commercial full-fat soybean flours.

Figure 13 contains data on vitamin content of soybeans before and after processing. There is no significant loss of any of these vitamins in processing. Of particular interest is the preservation of thiamine, which is quite heat labile.

After completing the experimental program, UNICEF sent approximately a ton of the extruded flour to the University of Taiwan, where it was utilized for acceptability and clinically supervised testing in an infant feeding program. In these tests, it was formulated with rice flour, sugar, and supplementary vitamins and fed to children from 4 to 12 months of age in comparison with milk and other soybean products. No proteins from animal origin were included in the diets. Reports from this test were very favorable and indicated that the soy flour supported excellent growth and development in the infants and that these gains were virtually comparable to those observed in babies fed cows' milk. A report of this experiment will be presented later today by Drs. Teply and Huang.

Preliminary cost studies have been made on the production of flour by the extrusion-cooking method. Processing costs are shown in Fig. 14 for flour produced by fine grinding the meats from the process and then classifying the finely ground material, as well as for a system that omits the classifying step. Estimated production costs for full-fat soy flour at various soybean prices are given in Fig. 15. The curves show that the price of soybeans contributes the greatest share of the flour cost and that a relatively small fluctuation in market cost can more than equal production costs.

Future Program

Our studies on soy flour research are continuing under the sponsorship of AID.

We believe the village-scale process is now ready for translation into developing countries. The follow-up of our process into nations overseas is now under consideration by AID staff members.

Studies on the extrusion-cooking process are continuing in order to develop basic and fundamental information. Figure 16 shows a photograph of our new pilot-plant extruder. This unit is constructed of stainless steel and is very flexible so that a great number of processing variables can be studied.

Initial studies have been concerned with feeding, handling, and operating characteristics of the extruder. Continuing studies will be involved in correlating processing conditions with the quality of the extruded product.

In these studies, it is hoped that totally new concepts in processing will be developed and that soybean foods superior in flavor acceptability, functionality, and oxidative stability can be produced.

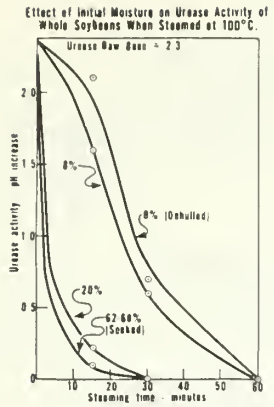
Effect of Initial Moisture on Urease Activity of Whole Soybeans When Steamed at 100°C.
Urease Raw Bean = 2.3
8%
8% (Dehulled)
20%
62.68% (Soaked)
Urease activity pH increase
Steaming Time - minutes

Figure 1

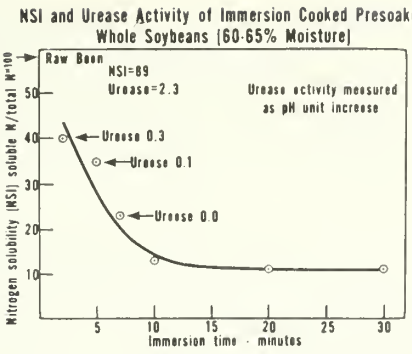

Figure 2

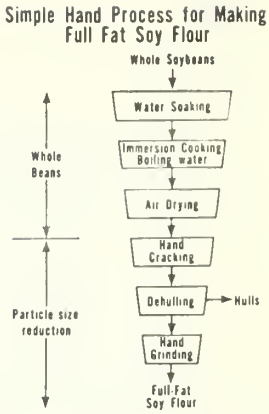

Figure 3

Soak - Cooking

Figure 4

Air Drying

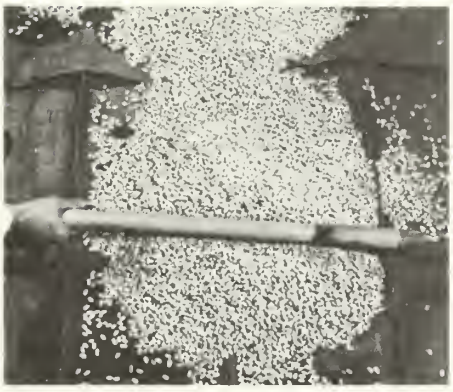

Figure 5

Hand Cracking

Figure 6

Winnowing

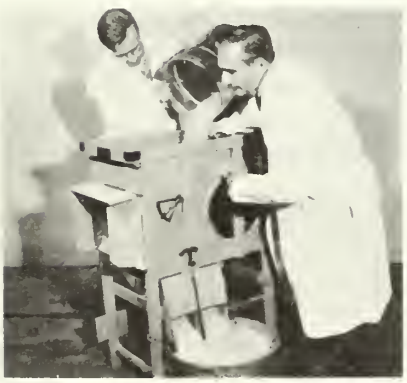

Figure 7

Winnowing - Schematic

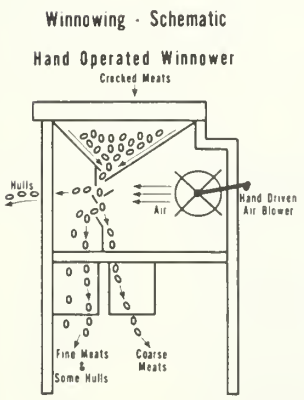

Figure 8

Grinding

Figure 9

Typical Composition of Immersion-Cooked Full-Fat Soy Flours

	%
Protein	41 - 42
Crude fat	20 - 23
Ash	5 - 7
Moisture	6 - 8
Crude fiber	2.5 - 3.0
Urease activity, pH change	0.0
Nitrogen solubility index, %	15 - 20
Available lysine, %	6.0 - 6.5

Figure 10

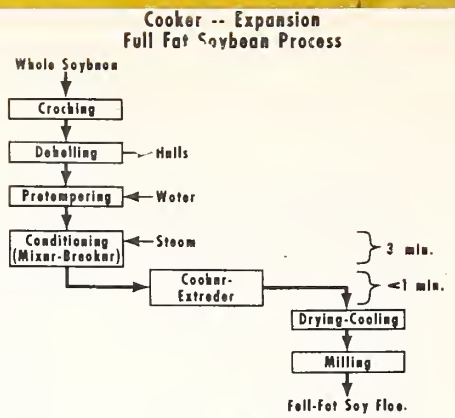

Figure 11

Proximate Analysis of Extruded Soy Flours

Protein, %	44
Crude fat, %	20
Crude fiber, %	< 3
Ash, %	5
Acid insoluble ash, %	0.02
Available lysine, % of protein	5.3
Peroxide value, meq./1000 g. extracted oil	0.40
Free fatty acid, % in extracted oil	0.50
Granulation	+95% thru 100 mesh

Figure 12

Vitamin Analysis

	Thiamin	Riboflavin	Niacin
	micrograms per gram		
Original flakes	9	2.9	50
Extruded F.F. flours			
Test A	9.9	3.1	63.0
Test H	9.5	2.9	47.0

Figure 13

Estimated Processing Costs for Typical Plants Producing Full-Fat Soy Flour from Dehulled Soybeans

Whole beans processed per day, tons	14	30	48	28	60	96
Whole beans processed per hour, tons	2	2	2	4	4	4
Shifts of operation per day	1	2	3	1	2	3
Processing costs, cents per lb. of flour (no classifying)	0.63	0.50	0.45	0.50	0.40	0.36
Processing costs, cents per lb. of flour (with classifying)	0.76	0.58	0.51	0.63	0.48	0.42

Figure 14

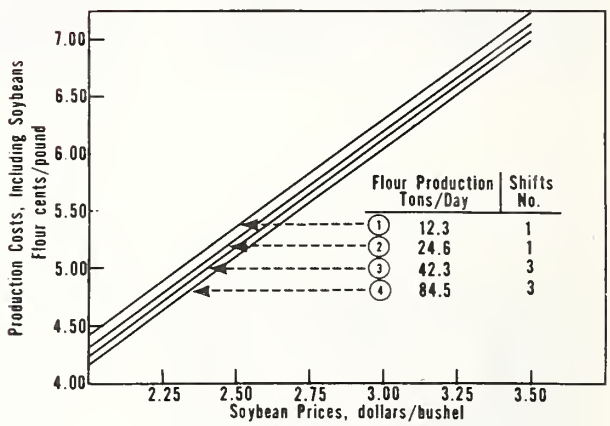

Figure 15

NU Extruder - Cooker

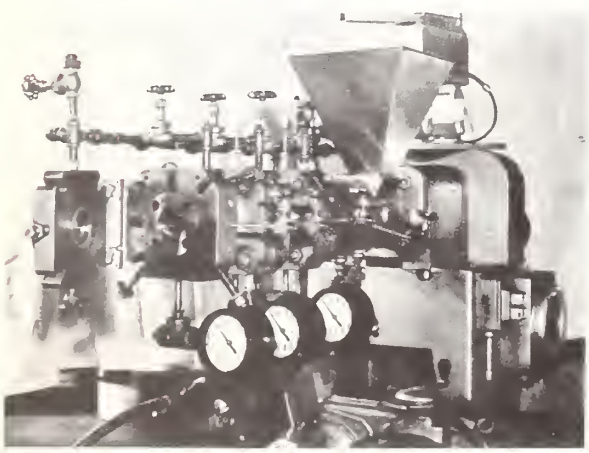

Figure 16

MEAT ANALOGUES FROM MODIFIED VEGETABLE TISSUES

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We have heard much on the preparation of essentially textureless end products from one fraction or other of the soybean during the past day and a half of presentations to this Conference. As an extension of the three preceding papers this morning, I would now like to share with you some facets of the state of the art in the conversion of relatively pure native oilseed protein into fine monofilaments. The purpose of such monofilament manufacture, to provide a digestible textural base for a whole new class of foods, may, on first glance, appear frivolous. Why, one might ask, go to the trouble to convert what is already a perfectly good food, through a somewhat elaborate process, into something which is no better nutritionally, particularly when confronted with the necessity to close the global gap between required per capita daily amounts of protein and that available, now and in the future (1, 2).

Since our time is somewhat limited, I will use, as my example, the "spinning" of soy isolate into monofibrils (Fig. 1). My remarks are equally applicable to all the other oilseed proteins, to casein, and indeed to any other protein that can be dispersed in either acid or alkaline media and forced through textile-type wet spinning dies into coagulating baths, which are maintained at or near the isoelectric point of the protein being used. There are many other approaches to texturization, such as the formation of chewy gels and the direct use of soybean grits or of concentrates produced by leaching out of the simple sugars, inorganic constituents, and other low molecular weight materials from soy meal. There is, as well, a whole sector of technology based on the formation of alginate filaments, which can carry a burden of dispersed proteins. I must apologize to the proponents of these other approaches to texture and limit myself to a discussion of the spinning of relatively pure isolate and of its incorporation, with the aid of binders, flavors, dyes, and other edibles into new and interesting foods capable of a very broad spectrum of resemblance to many of our most familiar and sought-after food categories (Fig. 2). This technology has, as its base, U.S. Patent 2,682,466, licenses to which are held by General Mills and others.

At General Mills, we have a sizeable and very active program that has been underway for the past 4 years. It represents a coherent group of many disciplines, all focused on the commercialization, domestically, of such products. Currently, we conduct research and development on, and manufacture modest amounts of, finished materials of the general class which can be thought of as analogues of natural meats. Our capability permits us to support limited test markets, both for ourselves and for various other food

companies with whom we work very closely. Some of you may already be familiar with our "bacon" analogue (Fig. 3), which is under limited test market both at the retail level and as a hotel, restaurant, and institutional item. You may also have encountered a modification of this analogue as the textured and flavored component in Skippy Peanut Butter with Smoky Crisps, currently being test marketed by the Best Foods Division of Corn Products Company. Other test markets of other analogue categories are now underway, and more will follow, both from General Mills and other food companies to whom these materials are being supplied. Worthington Foods have been in the market place for several years with a variety of spun products.

There are compelling reasons, both at home and abroad, for the formulation of foods of familiar texture, flavor, appearance, and bite. From the biochemical point of view, of course, textureless powders of high quality protein are perfectly adequate. From the extremely important physiological, emotional, and sensory aspects, texture in food, at least in certain classes of food, is of paramount importance. To obtain full gratification and indeed full nutritional value from foods, at least in the human species, they must be enjoyable to consume. Enjoyment of foods is the net result of all of the sensory values of flavor, odor, texture, bite, mouth feel, and mouth disappearance.

A food manufacturer ignores, at his peril, the net result combination of the afferent and efferent nerve impulses which are set up during the process of biting, mastication, tasting, and swallowing of foods (3). This extraordinarily complex mechanism, which has its beginnings in the degree of tension and relaxation of the jaw muscles, extends on to the root sockets of the teeth and includes the myriad components involved in the stereognosis of food in the mouth. This stereognostic, or dimensional recognition effect, results from the combination of nerve impulses set up in the tongue, the gums, the lips, the walls of the cheeks, and the roof of the mouth. The sensitivity and the systemic impact of these sensory mechanisms tends to be overlooked, yet each of us who still possesses his original dentures knows how easy it is to detect the tiniest grain of silica in spinach, for example, or, without touching the lips or the tongue, to detect both the thickness and the surface texture of a thin sheet of paper placed between the upper and lower incisor teeth. Carried by the cranial nerves to the central nervous system and from thence to the gastrointestinal tract and radiating throughout the entire body, with appropriate feedbacks such as satiety, for example, these oral, nasal, and ocular impulses place textured foods in a completely different gustatory class from bland, amorphous mixtures.

While there are exceptions, the preparation of the protein monofilaments on which this new class of foods is based generally requires that the protein fed to the spinning step be of a purity level of 80 percent or higher. Speaking generally, the oilseed proteins, which are the materials of choice for digestible monofilament production, should be purified to an initial level of 90 percent or better in order to perform satisfactorily in continuous production equipment. Theoretically, any protein can be spun, if one wants to do so, but, as a practical matter, the oilseed proteins such as soy,

cottonseed, corn, sunflower, safflower, and peanut, because of their intrinsic chemical properties and their normal molecular weight distribution, appear to be the most suitable for spinning purposes and, fortunately, possess a relatively high nutritional value as exemplified by their protein efficiency ratios, net protein utilization, and biological value data.

Beginning then with isolated soy protein, in alkaline dispersions of 10 to 20 percent protein solids adjusted to pH values above 10, one achieves a spinning "dope" of a translucent appearance and golden hue, which possesses pseudo-plastic rheology and somewhat resembles liquid honey in appearance. When such an alkaline dispersion is forced through a standard, noble metal wet spinning "spinnerette" and emerges in a coagulating bath adjusted to the isoelectric point of the particular protein being used, precipitation occurs; and, if this precipitate is drawn away continuously from the discharge face, then monofilaments may be produced endlessly, so long as the alkaline dispersion is supplied under pressure and the coagulating bath chemicals are kept replenished. Such isoelectric baths are usually composed of an aqueous solution of any food grade acid and often contain dissolved electrolytes as well. A suitable system for soy isolate could then be acetic acid and sodium chloride.

Since the ultimate texture of the food analogue being prepared depends, to some degree, on the diameter of the monofilament, then it follows that the choice of spinnerette hole size is important. We prefer to work with spinnerettes having capillary diameters below 0.008 inch, but larger size monofilaments are perfectly feasible. Another parameter of texture is produced by the degree of toughness or tenderness of the individual monofilament. Several controllable factors contribute to ultimate shear or tensile strength recorded by the teeth during mastication. For example, a greater degree of alignment and parallel interlock of the alkali-unfolded protein molecules can be obtained by deliberate stretching of the monofilament just after spinning and by heat setting of the resultant stretched material in order to obliterate its plastic memory. Such stretching and heat setting is best conducted while immersed in a second bath of the same composition as the coagulating bath. A stronger and tougher monofilament of smaller diameter than the original is thus produced.

There are other ways and means of increasing or decreasing resistance to bite and of varying the texture of the finished foods. This morning, I will mention only one other. If the bundles of fibrils, or "tows" (to introduce a further textile term), end up in the finished food in their initial parallel arrangement to approximate the palisade structure so familiar in chicken breast or seafood, for example, then a texture is produced which is discernibly different from that obtained when a high degree of randomization of fibers is present in the finished food; for example, in simulated ground beef. It is in the compounding of finished goods from the washed, moist monofilament tows and extrinsic ingredients that the great

versatility of this technology and the precise controllability of the nutritional and sensory values becomes apparent (4).

In our hands, such textured foods usually contain, on a dry weight basis, somewhere in the range of 1/3 to 2/3 of their final dry weight as spun monofilament. The balance is composed of vegetable or animal fats or both, flavors, supplemental nutrients such as vitamins and minerals, an all-important thermo-setting binding system, and other edible materials almost at the whim of the fabricator. Since the monofilaments are colorless, odorless, and tasteless, then the degree of resemblance to animal food counterparts is a matter of proper choice of ingredients; and the variations possible in the merits of the final products are quite literally without limit (Figs. 4 and 5)

A typical dry product would contain approximately 60 percent protein, 20 percent fat, 17 percent carbohydrate, and 3 percent ash, but here again the final levels are at the discretion of the technologist. All such products, as initially manufactured, are cooked and usually fall in the 50 to 70 percent moisture range. Such moist products can, of course, be consumed directly, can be refrigerated, canned, frozen or dried, and can assume any desired final geometry, with the exception that, where dried products are sought, there are upper limits on dimensions. I assume that most of you had an opportunity at the reception last evening to sample some of these products, and I trust that they met with your approval.

The dry products have outstanding built-in convenience characteristics. Circulating among you at the moment are some examples of a partial range of such dry products. The "bacon" analogue is best used without rehydration; the other representatives regain their meatlike characteristics after brief immersion in hot water. These dry products, all of which are precooked, require no refrigeration and, provided they are protected from moisture, have long shelf lives. I trust you will agree with my colleagues that these items, which even after rehydration have extremely high protein levels, begin to approach the ultimate in convenience. It is always very tempting to refer to this new class of foods as "synthetic," "substitute," "imitation," or something-or-other. As you will have gathered by now, they are no more synthetic than is cheese or sausage or spaghetti. They are simply precisely engineered, processed foods of a new category, derived from classical food materials that have been so rearranged and combined as to achieve desirable new sensory characteristics.

A casual examination, by anyone in this audience, of the ingredient formula of any representative of this new class of foods would enable such an examiner to predict, fairly precisely, the nutritional level which would be present in the final product. Since severe heating is not used in their preparation, then the protein efficiency ratio can be guessed at by merely knowing the amount of soy protein, wheat gluten, egg albumin, and other protein components present. Similarly, from the proximate composition, the

caloric value can readily be estimated. We, in General Mills, have chosen, notwithstanding, the route of rather elaborate nutritional studies on this class of foods. These studies have been conducted by the Wisconsin Alumni Research Foundation, by Dr. Bressani (5) and his colleagues at the Institute of Nutrition for Central America and Panama, and by Drs. Hodges and Krehl (6) at the University of Iowa. The findings of the latter two groups will be published in detail in the near future. The PER value of the finished product has been demonstrated to be at about 90 percent of that of casein. The Guatemalan studies were conducted both with small animals and in children recovered from kwashiorkor. These studies demonstrated that in weanling rats the PER value, with no amino acid supplementation, is 2.30, a value similar to that found for dehydrated beef run concurrently. In dogs, Dr. Bressani's group demonstrated that the nutritive value of our "ground beef" analogue and that of natural beef were essentially the same. No adverse effects have been demonstrated in any species at any level of intake. Dr. Bressani concludes that the protein quality of textured soy food is high, about 88 percent of that of milk, with adequate digestibility, ready acceptability, and freedom from adverse physiological effects.

In the Iowa studies (6), which were multi-phasic, similar excellent nutritional response was obtained in human adults. Since these results are still to be published in detail, I will refer only to phase 1, which involved six healthy adult male prison volunteers. Rigid dietary control was effected in a metabolic ward for a period of 6 months, with frozen Bontrae (7) as the protein source. Fats used were unsaturated vegetable products of zero cholesterol content and contributed either 15 or 45 percent of the caloric level. Carbohydrates were alternated between sugar and starch. Elaborate blood and excreta studies were conducted. All subjects remained in nitrogen balance and, by all of the many criteria used, were adjudged to be in excellent health throughout. In short, the Guatemalan and Iowan studies demonstrated clearly the excellence of this food class both under the high anabolic demand of the preschool child and the maintenance requirements for the adult human. In the case of the adult prisoners, as would be expected, the blood serum cholesterol levels fell precipitously to about 100 mg. percent below pretest values and remained low throughout.

Textured foods based on spun oilseed proteins clearly have much to commend them. The digestible textural base of monofilaments can serve as the vehicle for the incorporation into man's diet of the bland, textureless powders produced by the fish protein concentrate technology or the more bizarre, but certain to be required, powders from algae, bacteria, yeasts, and so on grown on a wide variety of substrates. Poor performance, high fat level, natural meat carcass portions can also serve as part of the binding serum for monofibril foods, thus being literally rebuilt into food-stuffs which can better withstand the trials and tribulations of food processing, such as tumbling retort procedures.

The potential of this approach for the establishment of viable local industry in preindustrial, protein-poor nations is very great. Based on indigenous, currently wasted protein sources and/or the more bizarre powders currently under development in other laboratories, with lower cost labor and raw material and simplified engineering, they can answer many of the logistics problems which have been so baffling up to this time. They are shelf stable, precooked, and protein potent. They can fit easily into any ethnic, religious, or dietary pattern and can be modified to suit any parochial taste preference. Best of all, they are enjoyable to eat.

The economics, even here at home, are most favorable. As the most unfavorable domestic comparison, the simulated "ground beef" need cost no more than one-half the actual cost of cooked standard hamburger while providing more protein per unit.

My colleagues and I are pleased with the opportunity presented by this Conference to share with you the current status of this new technology.

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(7) Registered trademark of General Mills, Inc. for spun protein food.

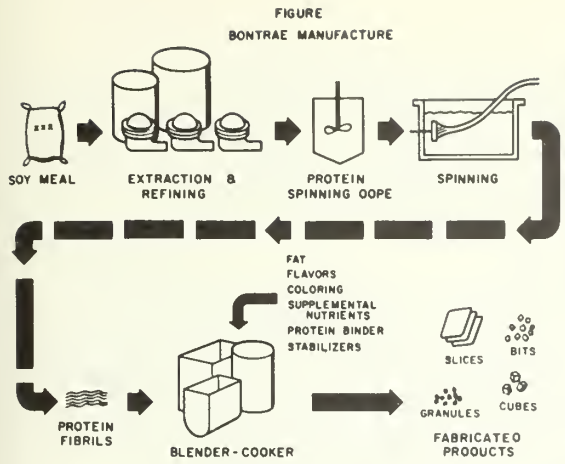

Figure 1. Diagram of Bontrae manufacture showing soybean meal being upgraded to 90% protein or better and spun into fibrils to which other nutrients, flavors and coloring can be added. The fabricated product can be sliced, ground or cubed as shown in figures 3, 4 and 5.

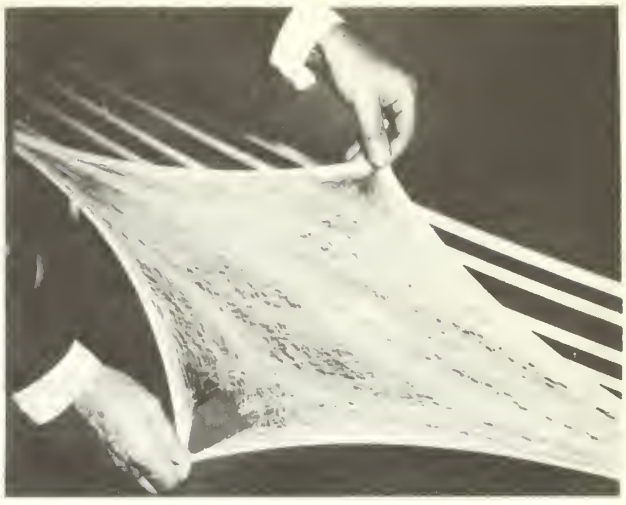

Figure 2. A "tow" consisting of 16,000 soy protein monofilaments simulates tissue found naturally in meat. With appropriate binders, colors and flavors, these fibrils can be formed into products that can be ingested with the "mouth satisfaction" of natural products. Spun soy protein fibers are completely digestible and when formulated with other nutrients, meat analogues have excellent nutritional qualities.

Figure 3. Bac*Os[1], crispy bits with a bacon-like flavor, are used to garnish the salad on the left with real fried crumbled bacon shown on the salad to the right.

[1]Registered Trademark of General Mills, Inc.

Figure 4. Scalloped potatoes with diced ham analogue, chicken analogue with a la king sauce, and a breaded seafood present manmade proteins in familiar dishes.

Figure 5. Sloppy Joe, sandwich and salad prepared with analogues of hamburger, ham and chicken show the versatility of these fabricated products.

FERMENTED PRODUCTS--MISO, SUFU, AND TEMPEH

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As some of you know, I have been greatly interested in the mold fermentations of soybeans, especially in the traditional food fermentations of the Orient (1). I shall briefly discuss three of these with which we have had some experience in the laboratory. The first is miso, a pastelike product used to add flavor to foods, especially soups; miso is produced extensively in Japan. Sufu, a solid cheeselike product, is somewhat like camembert cheese in appearance and is highly flavored. Sufu is a typical Chinese food. Tempeh is a solid bland-flavored product prepared from soybeans in the East Indies, and it is eaten as a main dish rather than used as a flavoring agent.

Miso

In 1961, at the Conference on Soybean Products for Protein in Human Foods held in Peoria, we reported in considerable detail on our studies on miso at the Northern Laboratory. Briefly, the process as outlined in this paper is diagrammed in Fig. 1.

Since that time utilization research work on miso has been confined to PL 480 projects, one of which is at the Central Miso Institute, Tokyo, with Dr. Hideo Ebine of the Japanese Food Institute being the principal investigator. Most of what I am going to discuss are results obtained from this project and personal observations I made this summer while in Japan.

Our PL 480 sponsored project in Japan involves the evaluation of miso made with dehulled soybeans from U.S. varieties. Work began in the middle of 1962. One of the problems we were confronted with in the research which Professor Shibasaki and I did here in Peoria was to find a suitable small fermentor that could be used to ferment the pastelike material. The usual tank fermentors designed for liquid media are quite unsuited for a solid substrate. In the Japanese project, small fermentors were specially built out of a clear plastic, like lucite; these were cylindrical and measured about 125 mm. in diameter by 140 mm. in length. In loading a fermentor, mash is carefully packed into the cylinder and a plungerlike lid fitted over the top so that pressure may be exerted on the fermenting mash. Pressure is exerted by a device resembling a car jack which has a center piston rod with a series of notches that make it possible to force the plunger down tightly into the mass of fermenting beans and koji. This is a most ingenious and effective small fermentor and serves ideally for testing varieties of soybeans

for making miso. Another piece of equipment developed was a machine suitable for dehulling soybeans to leave the cotyledons whole or broken in to one or two pieces. This equipment can handle 460 kg. per hour.

The qualities used to evaluate varieties of soybeans for making miso are as follows:

1. Uniformity of cooking before fermentation. The beans must soften rapidly and uniformly without too much heat.

2. Color. The soybeans must be uniformly light in color and must not have a dark-colored hilum.

3. Flavor of the product after fermentation.

Some information thus far obtained from this project:

1. Grits, i.e., beans dehulled and broken into a few fragments, fermented very well. A considerable amount of soluble material is lost during soaking and cooking grits. When soybean grits were sprayed with water to avoid loss of water-soluble matter, the resulting miso had a beany flavor and had a poor organoleptic score. The problem of loss of water-soluble material has not as yet been successfully overcome.

2. Miso made from grits as compared with that from whole soybeans showed some remarkable differences. The miso grits had the following characteristics:

   a. Sugars, including reducing sugars, were lower.

   b. Since grits absorb water faster, the miso had a higher moisture level and a softer consistency.

   c. The color of the miso was very fine.

   d. Very excellent white and yellow misos were produced.

   e. The numbers of yeast were much higher in the miso grits, and these organisms are very important in the ripening of the product.

   f. Organoleptic tests showed the score on miso grits was generally higher than that of whole bean miso.

3. The superiority of the method for making miso of high quality from soybean grits was confirmed on an industrial scale. Its only disadvantage is the greater loss of water-soluble material. The grits method was patented by us in 1961 in U.S. Patent 2,967,108.

4. Some 23 commercially available varieties of soybeans and 27 unnamed ones have been tested.

5. Among the varieties of soybeans tested, the best were Harosoy, Yelnanda, and Comet. Results indicate that for making all three kinds of miso, Comet was quite suitable.

The Japanese project was to run for 3 years but has been extended for 2 more years. Since its renewal, several additional varieties have been found to offer promise including Mandarin and Kanrich.

While in Japan, I attempted to get definite information on the amount of miso produced. In 1963 (the latest figures I could obtain), the amount of soybeans and soybean flakes employed in industrial miso manufacture amounted to 152,000 metric tons of which about 100,000 tons were imported. Eighty-three percent were whole beans. Of all the whole beans used in miso, 13 percent were domestic (Japanese) and the remainder from the United States and Red China. In 1964, about 300,000 metric tons of miso were produced in the home and 473,845 metric tons commercially. While in Japan, I saw one new, fully automated plant using Chinese beans. The manager said he had used beans from the United States until about December 1965; but, because he could not get suitable United States varieties, he had changed over to using beans from Red China, which are received in burlap bags.

Our second PL 480 project on miso involves an attempt by Professor E. Y. Diamant of Bar-Ilan University in Israel to produce a misolike product from oil-extracted soybeans. In Israel, considerable amounts of meal accumulate from soybeans purchased from the United States primarily for oil. Contrary to using whole soybeans, the starting material would be soybean meal, which for obvious reasons ferments differently than do whole soybeans normally used in making miso. All studies were made on a laboratory scale. Considerable success has been achieved in making a misolike product that involves a combination of the use of enzymes and fermentation.

Sufu

Sufu, or Chinese cheese, is a fermentation product made exclusively from soybeans and produced principally in China and Taiwan. Apparently not much is known about the methods of its preparation in Japan, but it has been made in China for many centuries. In our PL 480 program, we were fortunate to secure a project with Dr. N. S. Wai, Institute of Chemistry, Academic Sinica, Taiwan, who had worked on soybean cheeselike products.

According to information supplied us by Dr. Wai, sufu was known to have been produced during the Ching Dynasty (it lasted for 300 years, ending about 1911). Sufu was referred to in the "Food Encyclopedia," written in 1861 by

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Su-Hsuing who stated that sufu prepared from tofu was more digestible and was good for children, older adults, and patients. There is another publication which shows sufu was made prior to 1600. The process involves the preparation of bean curd (tofu) reportedly discovered sometime between 179 and 122 B.C.

The process of making sufu begins with whole soybeans which are washed, soaked overnight at room temperature, and then ground in a suitable mill. The ground soybeans as mash are pressed to extract soybean milk and this is heated in excess water. Typically, the milk is precipitated with calcium sulfate, and the curd is pressed into a mold, usually a wooden box, to remove much of the water with the solids remaining as a cake. The pressed cake next must be very carefully removed from the mold or box under water. The cake can then be sliced into small cubes, and this product is used extensively in the Far East as tofu (soybean curd).

Tofu obtained by Professor Wai had 9 percent water-insoluble protein, 0.3 percent water-soluble nitrogen compounds as protein, 4.0 percent lipids, and 83 percent moisture. Tofu has a bland taste and is white to very pale yellow or grayish. In making sufu, tofu is cut into small cubes approximately 2 x 2 x 4 cm. The cubes are sprayed with an acid-saline solution of 2 percent NaCl plus 0.8 percent citric acid or dipped in a solution of 6 percent NaCl and 2.5 percent citric acid. The cubes are then subjected to hot air sterilization at 100° C. for 10 minutes, a treatment which tends to reduce the moisture slightly and to dry the surface of the tofu. The dipping or spraying with salt and acid along with drying and heating of the surface of the cubes are steps taken to prevent contaminating microorganisms, especially bacteria, from growing. In the old method, cakes were exposed to the sun and partly dried. Also, in this method old trays were used, which were naturally heavily contaminated with the suitable mold spores to start new fermentations. After cooling the cubes, their surfaces are inoculated with a pure culture of the appropriate fungus. The cubes need to be separated from each other in a tray that is open at the bottom and top to allow free circulation of air and to enable the fungus to grow on all sides of the tofu.

Like all soy fermentations, the key to whether the process can result in a good product or not, depends on finding the proper microorganism. For sufu, the fungus used must have the following characteristics:

1. Mycelium, that is the filaments of the mold, must be white or at most slightly yellowish.

2. Texture of the mat formed by the mold must be dense and tenacious so that a covering will be formed over the entire surface of the tofu to act as a protective coat for the curd.

3. Mold growth on a protein-rich medium, such as tofu, should never develop a disagreeable odor or astringent taste.

4. Suitable proteolytic enzymes should be formed, of course, without forming any harmful materials.

Prior to this study in Taiwan, we had secured cultures from various sources reported to have been used in making sufu. All were members of Mucor or a related genus Actinomucor, a genus intermediate between Mucor and Rhizopus. Professor Wai, knowing the process and when to make isolations at the proper stage, was able to collect the molds from several plants in Taiwan, Hong Kong, and elsewhere. He reported that the mold he consistently obtained was Rhizopus chinensis var. chungyuen. When he submitted cultures to us, they proved to be members of the fungus Actinomucor elegans. In isolations from homemade sufu, he was also able to demonstrate that several species of Mucor were used (including M. hiemalis and M. racemosus). However, we are fairly certain that A. elegans is the preferred organism used in commercial operations.

The inoculated cakes in trays are placed in an incubator with the temperature controlled at 20° C. although in some instances temperatures as low as 12° C. are used. After molding for 3 to 7 days, depending on the strain of fungus used, the tray is removed from the incubator and the fresh molded cubes are now known as pehtzes. According to Professor Wai, the pehtzes show the following analysis: Water-insoluble nitrogen protein 10.3 percent, water-soluble nitrogen compounds 1.26 percent, lipids 4.3 percent, and a moisture content of 73.9 percent.

The pehtzes are next brined in various solutions depending on the flavor desired. A typical brine would consist of 12 percent NaCl and 10 percent ethanol (sometimes added as rice wine). In other instances, only a salt brine may be used. The molded cakes are allowed to age for about 2 months. The finished cheese along with the brine is bottled, sterilized, and marketed as sufu (Fig. 2).

During processing, Professor Wai found that about 12 percent of the insoluble protein was hydrolyzed to peptides and amino acids.

Further studies in Taiwan have demonstrated that sufu may be kept for as long as 3 months. Currently, work is concerned with the types of enzymes formed by the sufu molds. For example, of all the various Mucor species tested, still the Actinomucor used commercially is the best proteinase producer and almost the best lipase producer. We have also looked at proteases produced by A. elegans. This same fungus is used in China to produce a food made by the fermentation of wheat gluten.

We have not been able to locate data on the amount of sufu produced annually in Taiwan.

Tempeh

Tempeh is an Indonesian fermentation of soybeans (2), which has received considerable attention at the Geneva (New York) Experiment Station and also at the Northern Laboratory. A simple laboratory procedure for preparing it is shown in Fig. 3.

In the East Indies, tempeh is prepared essentially as illustrated except some of the mold is taken from a previous fermentation and is used to inoculate soaked, cooked, dehulled soybeans. Instead of glass containers, the mass of inoculated beans is wrapped in banana leaves and allowed to ferment for the proper time, and then the packages are sold daily.

The tempeh fermentation has several intriguing aspects that make the process especially attractive for further study and development:

1. The fermentation is very short--not more than 24 hours.

2. The preparation of the single substrate--soybeans--is simple.

3. The food resulting from the fermentation is very bland and quite acceptable to most people who have tasted it.

4. The mold used has simple growth requirements and produces desirable proteolytic and lipolytic enzymes. It will grow on a simple ammonia, glucose, salts medium and under reduced aeration.

5. The fungus used comes from a group of fungi not known to produce toxic substances.

6. The white, colorless mycelium produces an attractive raw product and has an attractive odor.

7. Processing costs are low.

Our earlier work described the process in Indonesia (2), established the type of mold (Rhizopus) used in Indonesia (3), determined the growth requirements of the fungus (4), showed how the fermentation could be scaled up to use plastic containers or aluminum trays (5), and determined the nutritive value of soybean tempeh when fed to rats (6).

I should now like to review briefly our latest work on the preparation of some new foods based in part on soybeans but in which cereals are also incorporated. Our first study was to find what made Rhizopus oligosporus useful in the tempeh fermentation. Investigation of the mold growing in

liquid substrates showed that two proteolytic enzymes were present in the culture filtrates (7). One had an optimum pH at 3.0, and the other had its maximum activity at 5.5. Each was relatively stable at pH 3 to 6. The maximum production of the enzymes occurred after 72 hours. Interestingly, a higher proteolytic activity was noted in culture filtrates of the organism grown in a wheat flour medium than in soybean flour. We also obtained data which suggested that the enzyme systems appear to be inhibited by water-soluble soybean extracts. The water-soluble soybean extracts had been shown earlier by us to have antifungal activity against Rhizopus.

At the same time we decided to see if suitable strains of R. oligosporus and other Rhizopus species obtained from commercial soybean tempeh in the East Indies and elsewhere could be used to produce new, more nutritious foods by fermenting cereals alone or in combinations with soybeans. Two papers (8, 9) described these new products, and we have been issued U.S. Patent 3,243,301 on the process (10).

When we first began the study of new products, we thought that all strains of Rhizopus from tempeh might be satisfactory. It was soon apparent that only certain strains could be used with cereal or cereals plus soybeans. We now believe that Rhizopus strains with good amyloytic activity are unsuited since they break down starch to simple sugars, which are then used to produce organic acids. Only cultures of R. oligosporus, such as NRRL 2710, are suitable. We also soon discovered that good molding would not occur unless the wheat surface was pearled or abraded to allow the fungus to grow rapidly.

Initially, we prepared cereals for fermentation in the same fashion as we had soybeans; that is, the grains were soaked in water overnight, excess water was discarded, and the soaked grain was boiled and drained. However, we discovered that soaking in water was unnecessary, and instead, the dry grain could be softened by boiling and used directly. The time for cooking each type of cereal varied and each time had to be established. Good growth of Rhizopus occurred not only on wheat and soybeans but also on barley, rye, oats, and rice. On the other hand, several commodities including corn, sorghum, and peanuts did not ferment well with any Rhizopus strain tested. The products resulting from their fermentations had a loose texture, broke into pieces when they were sliced, and had a poor odor and taste when cooked.

After the fermentations of wheat, barley, rye, oats, and rice, cakes were formed just as with soybeans with white mycelium of the fungus binding the cereal grains together and sporulation did not occur to any extent. When wheat was fermented, the raw cakes had a fresh yeasty or even mushroom odor. However, with wheat difficulty was encountered in slicing the fermented product prior to frying. When the new types of tempen are fried, they have a pleasant flavor which varies with the starting substrate. For example, wheat tempen when freshly fried has a flavor of popcorn.

The product in which we became most interested was a fermentation of soybeans and wheat together. A typical example of how a fermentation of combined

substrates is made can be illustrated by the following experiment: Six hundred and sixty grams of cracked wheat were covered with 1,750 ml. of tap water and cooked for 12 minutes without pressure. The wheat was drained of excess water. Simultaneously, an equal amount of soybean grits (660 g.) was covered with 2,200 ml. of tap water, heated for 30 minutes without pressure, and the excess water discarded. The wheat and soybeans were then combined (3,025 g.), and inoculated in the usual fashion with spores of R. oligosporus NRRL 2710. The inoculated substrate was then packed in an aluminum tray, covered with a perforated plastic cover, and incubated at 31° C. At the end of 22 hours, the fermentation was complete, and the cake could be readily removed from the tray and cut into thin slices. Its weight then was 2,909 g.

Absence of Aflatoxin in Fermented Food Products

Recently there has been a great deal of concern regarding toxins (aflatoxins) formed by certain strains of Aspergillus flavus in agricultural commodities, especially peanuts. Some people have expressed concern over the possibility of toxins being formed by a relative of A. flavus, namely A. oryzae, which is used not only in making miso but also in other food fermentations, such as shoyu (soy sauce), hamanatto, sake, and others. When we first heard of the aflatoxin problem in A. flavus, we were interested in assaying samples of various fermented foods to see if they could possibly contain any toxic materials.

Our approach was to test cultures of Aspergillus oryzae and A. soyae for aflatoxin and also to check the products made with various fungi including A. oryzae. Our study of 53 strains of A. oryzae used commercially indicated that no aflatoxin could be detected. The details of this work can be found in a paper by Hesseltine and coworkers (11). Although many of the strains showed different fluorescent spots, none of these formed aflatoxin at levels of 25 p.p.b. or above. This work has been confirmed by a paper presented by T. Yokotsuka and coworkers (12) in September 1966 at the American Chemical Society meeting in New York.

A point that should be emphasized is the nature of reports on the occurrence of aflatoxin in foods. When thin-layer chromatoplates are run and no fluorescence is seen, obviously the sample is negative. However, if fluorescence is found after proper solvent extraction of the product, it is still not positive until a bioassay in the duckling test is positive. Therefore, further reports, which may appear in the literature on aflatoxin cannot be accepted as positive until a positive duckling test has confirmed the thin-layer chromatographic plates.

In addition to testing strains of A. oryzae and soyae, we have also made extracts of the following food products made by fermentation and found them all negative for aflatoxin at levels of 3 to 5 p.p.b. These products and their sources are shown in Table 1.

Table 1.--Mold fermented food products tested for aflatoxin and found negative

Name of food	Source	Fungus used
Shoyu	Japan	Aspergillus oryzae
Shoyu	Taiwan	Aspergillus oryzae
Miso	Japan	Aspergillus oryzae
Miso	NRRL	Aspergillus oryzae
Chinese black beans	Taiwan	Aspergillus oryzae
Hamanatto (2 samples)	Japan	Aspergillus oryzae
Moromi	Japan	Aspergillus oryzae
Katsuobushi	Japan	Aspergillus sp.
Soybean tempeh	NRRL	Rhizopus oligosporus
Wheat tempeh	NRRL	Rhizopus oligosporus
Rice tempeh	NRRL	Rhizopus oligosporus
Wheat-soybean tempeh	NRRL	Rhizopus oligosporus
Blue cheese	Domestic	Penicillium roqueforti
Gorgonzola	Italy	Penicillium roqueforti
Camembert cheese	Domestic	Penicillium camemberti

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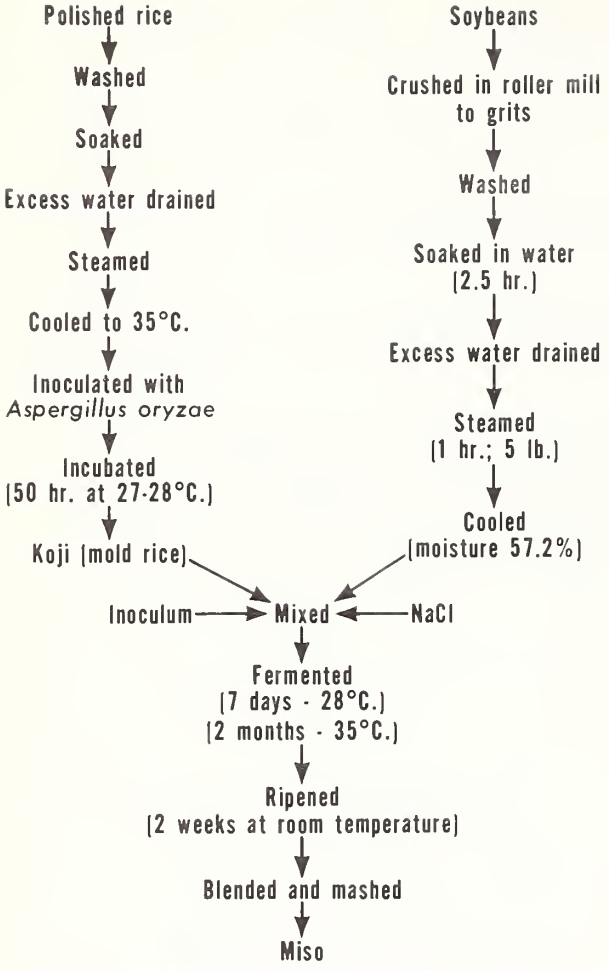

Figure 1. Method for preparation of miso.

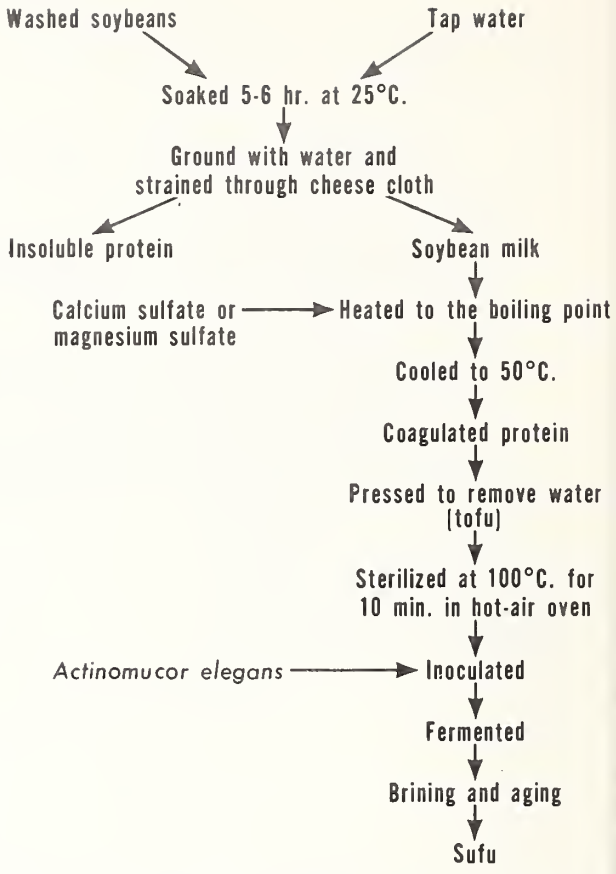

Figure 2. Flow sheet for the production of sufu.

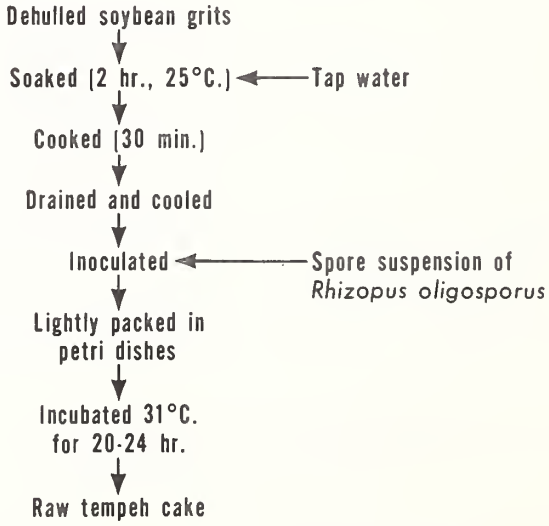

Figure 3. Laboratory process for making tempeh.

SESSION IV: MARKETING AND USE OF SOYBEAN PROTEIN PRODUCTS IN VARIOUS COUNTRIES

Max Milner, Presiding
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TAIWAN PROGRAM--EXTRUDED FULL-FAT SOY FLOUR

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My chief aim is to provide a brief background for the presentation by Dr. Huang. At the same time, I wish to say just a bit about the developments leading up to the Taiwan project, and to give some of the reasons behind the particular approaches used. Finally, I want to mention the cooperation among various parties which has brought the project to its present point. (We must bear in mind that the difficult task of introducing and marketing products still lies ahead.)

Contrary to popular belief, soy foods have not been used traditionally in Asia as a substitute for mammalian milk in the feeding of infants. Dr. Ernest Tso[1], of China, wrote in 1928: "Soybean milk is a native food used in certain parts of the country as a morning beverage but it is little used as part of the diet of children. Its nutritive properties as a food for young infants are practically unknown." Dr. Tso fed an infant for 8 months beginning at 6 weeks of age with soybean milk as the main source, though not the sole source of protein. He reported, "the experiment tends to show that, properly supplemented, soy milk can be made more or less comparable to cow's milk in its nutritive properties." Actually, for some years before Dr. Tso's investigation, considerable evidence was accumulating in the West on the nutritive value of soy preparations for humans, including young infants, and Western doctors, notably Dr. Harry Miller, began to introduce carefully prepared and handled soy milk in the feeding of infants in the Far East; in the West, standardized commercial soy preparations that could replace cow's milk in cases of allergy in infants became firmly established.

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[1] Tso, E. The development of an infant fed eight months on a soybean milk diet. Chinese J. Physiol. 2(1): 33-40 (1928).

One of the first government requests to agencies of the United Nations for assistance with respect to a product that might serve as an alternative to skim milk powder came from Indonesia about 15 years ago. Facilities were established to make a soy extract and to spray-dry it. The name "Saridele" was chosen for this type of product. A vitamin- and mineral-fortified, sweetened-flavored product was placed on the market; part of the output of the plant was distributed free to hospitals, etc., in the form of a simpler unsweetened powder. The company was able to sell in the retail market without difficulty all the sweetened-flavored product it could make. We have not had recent reports on this operation.

In the course of implementation of the Saridele project, certain basic difficulties were encountered in attempting to produce consistently a high-quality product retaining the maximum nutritive value. One problem was the lack of a regular supply of soybeans of a uniform quality and at a favorable price, which might have been alleviated through agronomic developments including extension services, and improved transport and soybean marketing.

The experience gained in Indonesia was applied when the Republic of China, Taiwan, requested assistance in the manufacture and distribution of a standardized high quality soy product suitable for infants and young children. For economy and maximum nutritional value, it was decided to concentrate on full-fat soy flour made from whole dehulled soybeans. The local authorities wished to confirm that simple formulations made from such flour would be satisfactory. Supplies of full-fat soy flours were shipped to Taiwan from the United States, and the Mead Johnson Company kindly made the services of J. L. Gabby available to advise, in Taiwan, on the preparation of mixtures for feeding trials. The World Health Organization and the Secretariat of the WHO/FAO/UNICEF Protein Advisory Group advised on the clinical testing procedures. An established commercial food firm in Taiwan undertook to manufacture full-fat soy flour and to manufacture and distribute supplementary foods containing full-fat soy flour. This firm purchased a high-pressure cooker/extruder for processing and the U. S. Agency for International Development provided a loan to facilitate this purchase. Earlier this year, UNICEF arranged to bring an engineer and a biochemist from the Taiwanese firm to the Northern Utilization Research and Development Division of the U.S. Department of Agriculture in Peoria, Illinois, to study soy technology. The biochemist also spent 2 weeks in Dr. David Hand's laboratories at Geneva, N. Y., and 2 weeks in an intensive flavoring course in the laboratories of a flavorings manufacturer. In May 1966, UNICEF's executive board allocated $50,000 to assist in the promotion of supplementary foods that are to be placed on the market by the Taiwanese firm. This, I think, is a good example of cooperative effort in this difficult field.

We are pleased that Dr. Huang is able to be with us at this Conference.

FEEDING OF INFANTS WITH FULL-FAT SOYBEAN-RICE FOODS

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[presented by Po-Chao Huang]

Reports by Chen and coworkers (1961), Hsu and Tzu (1963), and Chen, Hsu, and Wu (1965) have shown that protein-calorie malnutrition exists in Taiwan. As was discussed by Dr. Teply, there is a necessity of developing low cost, good quality, and acceptable protein-rich foods in Taiwan.

Using toasted and extruded full-fat soybean flours, which are called ADM and Wenger soybean flours, respectively, we have developed two kinds of protein-rich soybean-rice foods. I would like to present the results of a clinical trial in which infants of 1 to 6-1/2 months of age were fed with the soy-rice foods for a period of 6 months in a nursery. The purpose of this study was to show that the nutritive value of the soy-rice mixtures in infant feeding is comparable to that of cow's milk; and also of a commercial full-fat soybean product, Sobee, which was shown by Omans and coworkers (1963) to be nutritionally adequate to support infant growth.

Ingredients of the soybean-rice foods are shown in Table 1, and composition of the foods and the liquid formulae prepared for the infant feeding are presented in Table 2.

Table 1.--Ingredients of the soya bean-rice formulae

Ingredients	Percentage
Full-fat soya flour[1]	45
Precooked rice flour	15
Soya oil	10[2]
Sucrose	27.5
Salt mixture[3]	2.5

[1] Two kinds of soya flours, ADM and Wenger, were used in separate preparations.

[2] Soya oil was 5 percent and sucrose 32.5 percent during the first 6 months of the study.

[3] Calcium phosphate dibasic, 80.7 percent, sodium chloride 18.8 percent, ferrous sulfate 0.47 percent, and potassium iodate 3.2 mg. percent.

Table 2.--Composition of the formulae

Components	ADM Powder	ADM Liquid[1]	Wenger Powder	Wenger Liquid[1]	Sobee Liquid	Milk Liquid[1]
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Protein	20.4	3.3	20.2	3.2	3.2	3.0
Fat	19.9	3.1	20.0	3.1	2.6	3.0
Carbohydrate	45.0	6.9	45.3	6.9	7.7	7.3
Calories	441	68	442	68	67	68

[1] To 1,000 ml. each of the liquid formulae following vitamins were added: Vitamin A, 3,500 I.U.; vitamin D, 700 I.U.; thiamine 1.8 mg.; riboflavin, 1.8 mg.; niacinamide, 9 mg.; Ca-pantothenate, 5 mg.; pyridoxine, 1 mg.; and vitamin B_{12}, 3 µg.

The ADM and Wenger soy flours, products of Archer Daniels Midland Company and Wenger Company, respectively, were incorporated in one of the two soy-rice foods. Both the ADM and Wenger soya-rice foods contain approximately 20 percent protein, which supplies 18.5 percent of the total calories. The soya-rice liquid formulae were well accepted by the babies and had no raw, beany flavor. Rice starch gelatinized upon heating and prevented the soya flour from rapid settling. Vitamin E was not added as a supplement but was probably supplied adequately by soya oil. Powdered cow's milk used as the control food was a UNICEF brand. When infants reached 8 months of age, additional rice flour was added to the extent of 1 to 3 percent of the liquid formula. In addition to the formula, 30 mg. of ascorbic acid in a small amount of sugar solution were given daily to each baby.

Selection of Infants

Fifty-seven infants studied were selected from volunteer families. Their ages ranged from 1 to 6-1/2, but most of them were 3 to 4 months of age (Table 3). They were free from congenital or acquired physical abnormalities on admission. Their hemoglobin levels were above 10 g. percent, and their body weights between plus and minus 15 percent of the mean weights of normal Chinese infants of the same age and sex group. There was an exception of five infants of whom four were twin babies, who weighed at about minus 20 percent level. Prior to their admission, most infants were fed cow's milk; some received both breast and cow's milk; and a part of them were on breast milk only.

Table 3.--Grouping, number, and average age of babies

Group	Number of babies			Average age on admission	
	Boys	Girls	Total	Months	Days
ADM	9	7	16	3	19
Wenger	8	8	16	3	19
Sobee	3	5	8	3	18
Milk	4	7	11	3	0
Milk ← Soya	1	5	6	3	14
Grand total	25	32	57	3	16

Feeding and Care of Infants

Infants were randomly distributed into five groups with consideration of their sex and age and subjected to one of the following formulae: (1) ADM, (2) Wenger, (3) Sobee, or (4) cow's milk. Because the nutritive value of milk is well established and that of Sobee appreciated recently (Omans and coworkers 1963), the number of subjects in each of these two groups was less than that for the ADM or Wenger group (Table 3). The fifth group, also small, received both a soya-rice mixture and cow's milk for 3 months each. On admission, either the milk formula was given or one of three kinds of soybean diets was introduced gradually over a period of 10 days in one group each. All babies were fed five times a day and the amount of formula taken was recorded each time within an error of ± 5 g. In addition to the formula, some fruits such as banana, papaya, or orange juice were given three to four times a week. Also, some soy-containing (25 percent soy flour by weight) biscuits were given to babies older than 7 months.

Body weight, accurate to 10 g., and height of the infants were measured three times a week and twice a month, respectively. Body temperature was measured twice a day and frequency of defecation and nature of stools were checked and recorded.

Clinical Findings

Individual growth curves of body weight of the male infants on the ADM formula are shown in Fig. 1, clearly indicating that the soya-rice diet supported excellent body weight gain in most of the boys. Although less remarkable weight gain was observed in infants who were underweight on

admission, this tendency was also seen in the cow's milk group. Temporary falls of body weight, which can be seen in the figure, are mainly due to mild upper respiratory infections and/or acute diarrheas. The growth curve of an average normal Chinese male infant is based on the data of Chen, Hsu, and Wu (1965).

The growth of two pairs of identical twins, one male and one female, is particularly interesting (Fig. 2). One of the male twin babies (case 19) was put on the cow's milk formula and the other twin was fed with the Wenger formula (case 20). Their gains in weight and height were almost the same. One of the twin girls (case 39) was fed with cow's milk first for 3 months and then put on the ADM formula for another 3 months. The diet of other twin girls (case 40) was conversely changed from the ADM formula to cow's milk, each fed for 3 months. It can be seen from Fig. 2 that the ADM soya-rice mixture supported better growth than the milk formula in this particular pair of identical twins.

Figure 3 shows the growth curves of body weights of another four infants whose diets were changed from cow's milk to the soya-rice diets or vice-versa, 3 or 2 months on each. In cases 53 and 57, the weight gain was larger when on cow's milk; however, case 53 suffered from Summer fever while on the Wenger formula. Case 56 lost some of her weight when her diet was changed from the ADM formula to cow's milk but gained weight thereafter normally. Case 62 grew better while she was on the ADM formula than when she was on cow's milk.

Comparison of the cumulative monthly body weight gains from 4 to 10 months of age among the ADM, Wenger, and Sobee groups showed that among the male infants the best growth was attained by the ADM group, followed by the Sobee group; the Wenger boys gained the least weight. It suggested superiority of the ADM over the Wenger formula. However, no significant difference in weight gain was noticed among the groups of female infants.

In Figs. 4 and 5, the average cumulative body weight gains of the soya groups as a whole (ADM + Wenger + Sobee) and the cow's milk group are plotted against age and are shown together with those of the normal Chinese infants. There was little difference in monthly body weight gain between the three groups from 4 to 7 months of age, after which the gains of the former two groups were apparently larger than those of the average Chinese infants, especially in male. No meaningful difference was seen between the soya and the milk groups either in male or female throughout the period.

These data clearly indicate that the nutritive value of the full-fat soya bean-rice mixtures is comparable to that of cow's milk in supporting infant growth at the level of protein given, 3.5 to 4.5 g. per kg. body weight per day.

From the data of weight gains and the dietary intakes, protein efficiency ratio (PER) and feeding efficiency ratio (FER) were calculated for the individual infants. The results are presented in Table 4. Higher PER was obtained for the cow's milk and Sobee groups, 0.49 and 0.48, respectively. Average ADM and Wenger groups was 0.42 for both of them. FER of the former two groups, 2.18 and 2.26, were again higher than those of latter two groups, 2.03 and 1.98, respectively. However, none of the differences were statistically significant by the "t" test.

Table 4.--Protein efficiency ratio (PER) and feeding efficiency ratio (FER) of the formulas in infants

Formulas	Number observed	PER[1/] Mean	PER[1/] Std. dev.	FER[2/] Mean	FER[2/] Std. dev.
ADM	13	0.42	± 0.08	2.03	± 0.38
Wenger	13	0.42	± 0.07	1.98	± 0.36
Sobee	8	0.48	± 0.07	2.26	± 0.36
Milk	11	0.49	± 0.14	2.18	± 0.61

1/ Body weight gain in grams per grams protein ingested.

2/ Body weight gain in grams per 100 calories portion of the formulae.

Both PER and FER were calculated from the data of infants between 5 and 8 months of age, with the exception of two (ADM), which were data of infants from 6 to 9 months and another two (ADM), which were data of infants from 5 to 9 months of age.

Monthly body height gains of infants of all groups and the average of the normal Chinese infants of the same age group, either male or female, were about the same and the differences insignificant.

Shepard and coworkers (1960) and Ripp (1961) reported the development of goiter in infants fed with Mull-Soy or Soyalac, which was not supplemented with iodine. Our soya-rice preparations were fortified with iodine and no goiter was observed.

Stools were rather bulky on the soya-rice formulae compared with those of milk fed infants. Perianal dermatitis, generally mild, was a frequent complication encountered during the early period of feeding. This is the only disadvantage found with the soya-rice diets. Incidence of diarrheal episodes encountered during the study was about the same in all groups.

These infants at the time of discharge after a 6-month stay in the nursery were all within normal limits in terms of motor control, social reaction, speech reaction, intellectual grasp and play reaction as judged by the standard set by Shirley, Mary-Harvard School of Public Health.

Blood Data

On admission and 3 and 6 months later, blood samples of infants were analyzed for hemoglobin, hematocrit, serum total protein, albumin and globulins, urea nitrogen, cholesterol and phosphorus. Hemoglobin level of each group ranged from 11.4 to 11.7 g. percent on admission and from 12.4 to 12.9 g. percent 6 months later (Table 5). Similarly hematocrit values increased from 31 to 33 to 34 to 37 in 6 months without statistically significant differences between the groups. Serum total protein and albumin levels are shown in Table 6. Gamma-globulin levels were all within the normal range of 0.57 to 0.59 g. per 100 ml. of serum.

Table 5.--Hemoglobin levels (Hb) and hematocrit values (Ht)
(Figures in parentheses are the numbers observed)

Group	On admission	3 Months later	6 Months later
	Hb, g./100 ml.	Hb, g./100 ml.	Hb, g./100 ml.
	Mean Std. dev.	Mean Std. dev.	Mean Std. dev.
ADM	11.5± 0.98 (16)	12.2±1.20 (16)	12.5±1.02 (13)
Wenger	11.7± 1.62 (16)	12.4±1.38 (16)	12.9±1.19 (14)
Sobee	11.4± 1.27 (8)	12.4±0.69 (8)	12.7±0.76 (8)
Cow's milk	11.7± 1.08 (11)	12.4±0.86 (11)	12.4±1.22 (11)
	Ht, percent	Ht, percent	Ht, percent
	Mean Std. dev.	Mean Std. dev.	Mean Std. dev.
ADM	32 ± 2.6 (16)	34 ± 2.0 (16)	36 ± 3.3 (13)
Wenger	33 ± 4.5 (16)	36 ± 3.9 (16)	37 ± 3.6 (14)
Sobee	31 ± 5.1 (8)	34 ± 4.4 (8)	36 ± 2.9 (8)
Cow's milk	32 ± 4.2 (11)	34 ± 4.4 (11)	34 ± 3.8 (10)

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Table 6.--Serum total protein and albumin levels
(Figures in parentheses are the numbers observed)

Group	On admission total protein, g./100 ml. Mean Std. dev.	6 Months later Total protein, g./100 ml. Mean Std. dev.	6 Months later Albumin, g./100 ml. Mean Std. dev.
ADM	5.87 ± 0.58 (16)	6.30 ± 0.37 (13)	4.23 ± 0.29 (12)
Wenger	6.16 ± 0.56 (16)	6.44 ± 0.33 (14)	4.32 ± 0.30 (11)
Sobee	6.00 ± 0.41 (8)	6.50 ± 0.52 (8)	4.45 ± 0.22 (6)
Cow's milk	6.08 ± 0.55 (11)	6.17 ± 0.44 (10)	4.17 ± 0.49 (8)

Blood urea nitrogen, serum cholesterol and serum phosphorus levels are presented in Table 7. Again no significant difference in the analytical data was seen between the four groups, although somewhat higher serum cholesterol values were obtained for the cow's milk group.

Table 7.--Levels of blood urea nitrogen, serum phosphorus and cholesterol after 6 months on the formulas
(Figures in parentheses are the numbers observed)

Group	Blood urea N mg./100 ml. Mean Std. dev.	Phosphorus mg./100 ml. Mean Std. dev.	Cholesterol mg./100 ml. Mean Std. dev.
ADM	16.6 ± 2.3 (13)	6.3 ± 0.81 (13)	112 ± 13 (13)
Wenger	16.6 ± 1.5 (13)	6.6 ± 0.79 (13)	114 ± 16 (14)
Sobee	16.3 ± 1.8 (8)	6.5 ± 0.99 (7)	117 ± 21 (7)
Cow's milk	16.3 ± 2.5 (10)	6.8 ± 0.73 (11)	127 ± 18 (10)

Omans and coworkers (1963) showed higher serum phosphorus and cholesterol levels in cow's milk fed infants than in those fed with soya diets. However, our soya formulae were supplemented with phosphorus and thus the serum phosphorus values of the soya infants were not lower than those of milk fed infants.

Nitrogen Balance Studies

Two boys of the milk group and three boys each from the ADM and Wenger groups were subjected to 5-day period nitrogen balance studies. The results are summarized in Table 8. The average apparent digestibilities of proteins of each diet were 84, 83, and 88 percent for the ADM, Wenger, and milk formulae, respectively.

Table 8.--Daily metabolic balances of nitrogen

Subject and group	Age days	Body weight. g.	Daily balance of nitrogen				
			Intake, mg./kg.	Output[1], mg./kg.	Retention mg./kg.	Retention Percent of intake	Apparent digestibility, percent
ADM							
K.C.	221	7,750	638	468[2]	170	27	81
	256	8,150	557	436[2]	121	22	83
L.W.	273	10,100	525	394 (12)	131	25	87
R.C.	307	8,610	549	432 (15)	117	21	83
Wenger							
W.P.	266	9,000	557	390[2]	167	30	79
	300	9,210	570	467 (23)	103	18	75
S.C.	265	9,155	631	429 (15)	202	32	87
	292	9,820	504	402 (12)	102	20	82
T.C.	305	7,380	690	544 (10)	146	21	88
Milk							
S.K.	256	8,520	559	373[2]	186	33	84
C.Y.	305	8,205	630	505 (13)	125	20	92
	318	8,260	556	434 (12)	122	22	90

[1] Nitrogen output includes dermal losses, which are shown in the parentheses.

[2] Dermal loss was not measured and was assumed to be 20 mg./kg., Joint FAO/WHO Expert Group, 1965.

Nitrogen retentions were 24 percent of intake for both the ADM and Wenger groups, and 27 percent for the milk group. Although higher figures were obtained for both nitrogen retention and digestibility for the milk group, the amount of nitrogen retained per kilogram body weight by the boys fed with the soya-rice formulae was not smaller than that reported for infants on pasteurized human milk (Fomon, 1959). Dermal losses were estimated by determining the nitrogen of water samples used for washing skin and for soaking the underwear of the infants every day during the period. The dermal nitrogen losses measured with these infants were 14 + 4.0 mg. per kilogram body weight per day. This figure is higher than the data of 10 mg. per kilogram per day reported by Cooke, Pratt, and Darrow (1950).

Discussion

It was established by Hayward and Hafner (1941) that the first limiting amino acid of soya bean protein is methionine as determined with chicks and rats. It was also shown in children that supplementation of processed soya flour diet with methionine increased its biological value (Parthasarathy and others, 1964). However, at the protein level actually taken by the infants of this study, 3.5 to 4.5 g. per kilogram per day, the methionine or the total sulfur-containing amino acids intake is likely to be adequate for the infant's need. Rice in the formula contributes 5 percent of the total protein. When the protein intake is 4.0 g. per kilogram, either of the soya-rice formulae supplies 55 mg. per kilogram of methionine which is higher than the suggested minimal requirement of infant, 45 mg. per kilogram (Hold and coworkers, 1960). Fomon and coworkers (1964), reported that 1.5 to 1.9 g. of soya protein per kilogram body weight was enough to give normal nitrogen retention and also support normal growth in their subjects of 60 to 102 days of age. However, Graham (1964) observed signs of protein deficiency in his infants when 1.75 g. per kilogram of soya protein was the sole source of dietary protein. From the viewpoint of safety and also for the easiness of feeding, the protein content of the liquid soya-rice formulae was set at 3.3 percent level. When the amount of soya flour was reduced and rice flour increased, the liquid formula was too thick to be fed easily. The authors consider, however, this technological problem can be solved and the formulae might be fed safely at 2.5 to 3.0 g. of protein per kilogram body weight level.

For many centuries Chinese have used varieties of soya bean products in their daily diets. However, the use of soya foods in infant feeding, even in the form of "soya milk," has been quite limited. Most of the pediatricians as well as the mothers have little familiarity with or are convinced of the value of soya preparations in the artificial feeding of babies. It is hoped that the results of this study will be acknowledged, and the economic soya-rice formulae will be used in daily practice of infant feeding when cow's milk cannot be afforded. They can be used as the entire diet or as a supplementary food.

Summary

Two kinds of protein-rich full-fat soya bean-rice diets, ADM and Wenger formulae, were prepared. These formulae, together with an American commercial full-fat soya product, Sobee, and a cow's milk formula were fed to 57 infants of 1 to 6-1/2 months of age for 6 months in a nursery. The protein intake of infants was at the level of 3.5 to 4.5 g. per kg. body weight per day.

Infants fed on the soya-rice formulae and Sobee gained body weight and height at a rate comparable to that achieved by infants fed cow's milk.

Blood analytical data showed that no significant difference existed between the test and the control groups in hemoglobin, hematocrit, serum total protein, albumin, phosphorus and blood urea. Slightly higher serum cholesterol level was noticed in the cow's milk group.

Nitrogen balance studies with eight infants showed that both nitrogen retention and digestibility were slightly higher with cow's milk than with the soya-rice formulae.

It was concluded that the soya-rice formulae can be used safely as a sole diet in infant feeding.

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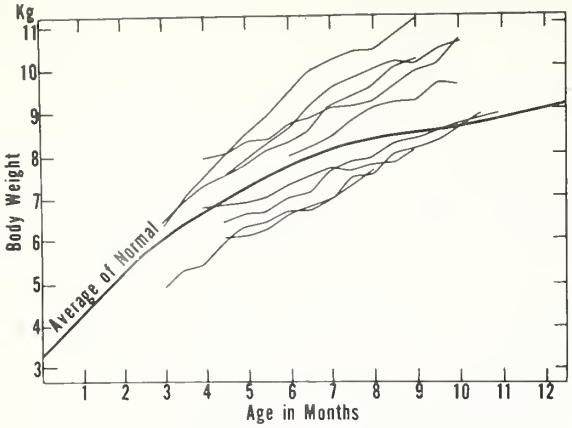

Figure 1. Body weight curves of the boys fed with the ADM formula.

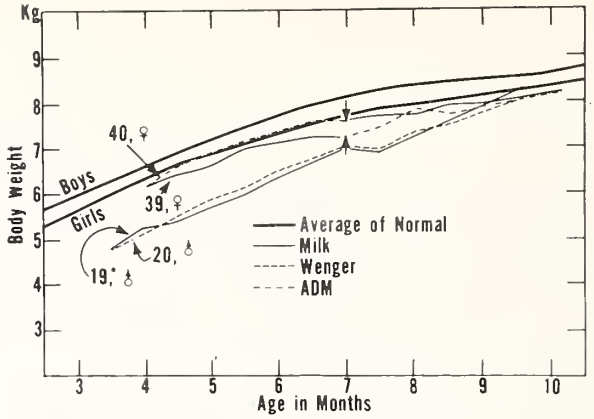

Figure 2. Body weight curves of the two pairs of identical twins.

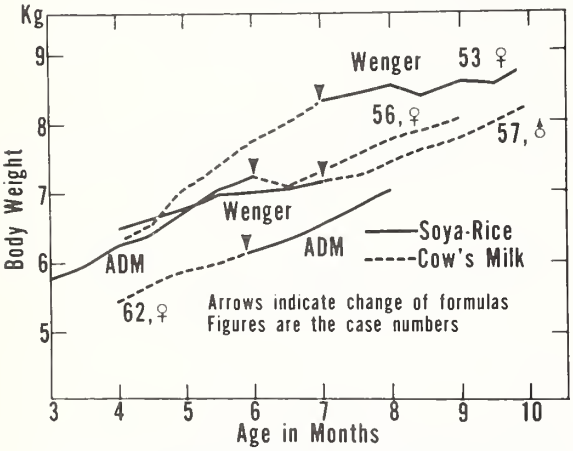

Figure 3. Body weight curves of babies whose diet was changed from cow's milk to soya-rice formula or vice-versa.

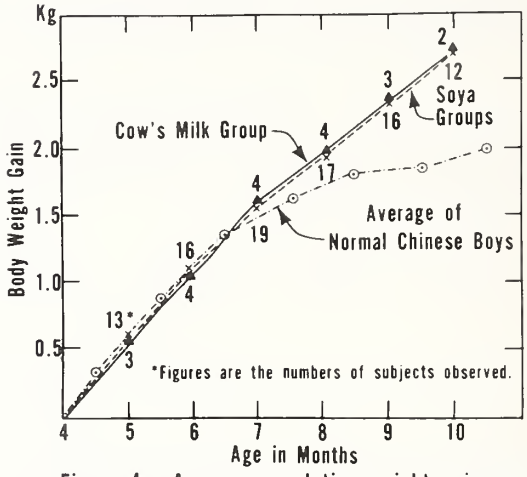

Figure 4. Average cumulative weight gain curve of boys of the soya groups as a whole (ADM, Wenger and Sobee groups) compared with curves for cow's milk group and normal Chinese boys.
(From the data of Chen and coworkers, 1965).

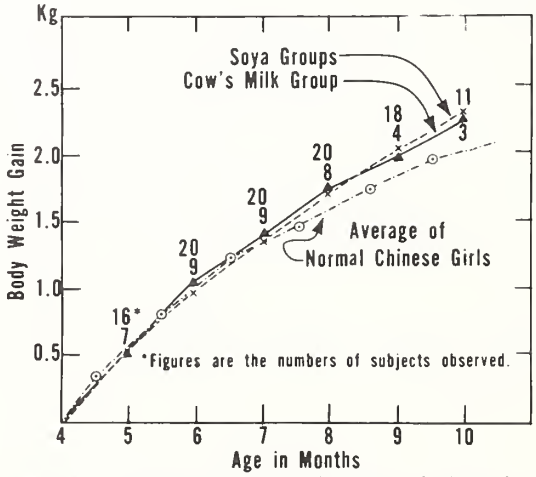

Figure 5. Average cumulative weight gain curve of girls of the soya groups as a whole (ADM, Wenger and Sobee groups) compared with curves for cow's milk group and normal Chinese girls).
(From the data of Chen and coworkers, 1965).

MARKETING SOY PROTEIN PRODUCTS AND PROBLEMS OF ACCEPTANCE IN FOREIGN COUNTRIES

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Looking back in the early history of man's existence on the earth, it appears that he intuitively selected foods in the form of wildlife, both plant and animal, which permitted growth and development, maintained reasonably good health and permitted propagation of the human race. The first children born of woman must have been nursed intuitively by the mother in the same way as is done by wild and domestic animals. As man's intelligence developed, he learned of those natural foods which seemed to be good for growth and development and discarded those containing toxic elements which could result in various physiological disturbances or death.

As the population increased in an area, and wildlife, at least in the form of animal life, became less plentiful, families moved on to areas of more plentiful supplies. Through accidental development and observation, man discovered that fermentation processes not only allowed him to store certain foods over longer periods of time, but developed certain flavor characteristics which man found desirable. Some of these foods were highly acceptable, promoted better growth and development and good health, while giving variety to the diet.

Books on ancient and modern history describe feasts which, even by today's standards, possessed the nutrients that are now recognized as necessary and desirable, even though in some cases they were not necessarily always consumed in a good balance. As man's intelligence further developed and facts were recorded in writing, communication was improved, and his desire to change from a nomad existence to development of more stable community life, he began cultivation of farm crops and fruits, and animal breeding for food purposes.

Due to differences in climatic conditions, terrain, location of populations inland and on the sea coast, differences in natural flora and fauna in various areas of the world, the natural selection of plant crops and the methods of preparation of these crops for food purposes, extremely diverse diets in various sections of the world has been the result. Through hundreds of generations, the food habits of the various people have developed in such a way as to become firmly entrenched, resulting in established taste habits, religious taboos, and superstitions. Thus, the introduction of new foods into such areas often presents quite a problem.

In those countries where the educational system has been highly developed so that the literacy level is extremely high, where communication in the form of lectures, printed material in the form of books, magazines, pamphlets, and newspapers are widely disseminated, where radio and television communications are highly developed, where techniques of agricultural production, food processing, transportation, food product development and research are well established, where marketing procedures and distribution channels are highly developed, and where people have money available to buy highly developed processed foods of all types, the people learn of new foods and ingredients and will accept changes in food habits much more readily than in those countries which are poorly developed from the standpoint of the factors just listed.

Changing of food habits is not easy. We are all fully aware that even in the case of the starving population, even though they may eat scrawny dogs and rats, it is not easy to convince them to eat many foods which are strange to them. If some ingredient is added to their native foods, resulting in a texture, appearance or flavor foreign to that which is familiar in that type of food, the acceptance level of the so-called "improved" food will be very low or almost nonexistent.

While the subject of this presentation is "marketing soy protein products and problems of acceptance in foreign countries," it might be well to review briefly some of the problems of marketing edible soy products in the United States. These edible products include soy flour and grits, isolated soy proteins, soy protein concentrates, soy milk products, and enzyme hydrolyzed soy proteins.

Soy flour and grit products have been available in the United States for about 30 years. While marked improvements have been made in soy flour and grits, from the standpoint of producing products with a variety of physical characteristics, lower bacterial counts, cleaner products, etc., unfortunately no one, to date, either in the United States or elsewhere, has designed a soybean processing plant, with a system having good sanitary features and material handling, specifically for the production of soy flour and grit products and other specialty soy protein products. Actually, with some exceptions, very little research has been done to produce a truly improved soy flour or grit product, from the standpoint of flavor, although decided improvements have been made from the microbiological standpoint. Most manufacturers of soy flour feel that the purchasers of soy flour and grit products would not be willing to pay a premium over that for the present types of products. In some cases, this belief is probably justified, but there is no question that flavor problems have had a marked effect in the acceptance of soy flour and grit products for a variety of uses and has limited the level at which these products can be used in finished foods.

The nutritive value of soy protein has been recognized for many years by animal nutritionists, but the real recognition of the potential value of

soy proteins for human feeding, with some exceptions, has only been recognized about 10 years by many human nutritionists. During World War II, when a shortage of meat and milk proteins existed, there was a considerable demand for soy flour and grits. Unfortunately, many of the people involved in the production and application of these products to the food industry did not have sufficient knowledge of soy flour and grits and certain important aspects of production. As a result, many materials were improperly produced and used in ways which resulted in finished foods with flavor and physical characteristics that were not acceptable to consumers.

During and after World War II, soybeans and soybean products were widely used in Germany in an attempt to alleviate the animal protein shortage. Since little knowledge was available as to how products should be used, many unpalatable foods were served, resulting in the development of a definite distaste for foods containing soy. After the war soy flour products were shipped from the United States to various European countries for addition to sausage products in order to stretch meat supplies. Meat processors, greedy to increase their profits, were producing so-called "sausage" using little meat and large amounts of soy resulting in a bad name for soy, which the manufacturers of soy products are still having to "live down." The same situation existed to some extent here in the United States, but we seem to have been more successful in gaining acceptance of soy protein-containing products due to improvement of soy products, production of new, more acceptable forms, showing food manufacturers the right type of product to use for a given application and educating them as to use limitations. It has taken about 20 years of effort on behalf of those producing various types of soy products to convince manufacturers of foods that when soy products are properly made and applied to food usage, the economics, functional qualities, and nutritional properties of soy products are of advantage to the food producer and the consumer. For the most part, the use of soy flour and grit products in foods has been primarily to take advantage of the physical and functional properties of many of the soy products, rather than to improve nutritional value of foods. However, there are some definite exceptions to this.

Many of our food laws and those of foreign countries were supposedly designed to protect the consumer from the standpoint of health, aesthetics, and economics. While these aims have been generally met, the real formulation of some of these regulations were based on political pressure by special interest groups who were trying to protect their own interest, often through foolish and prejudicial thinking and ignorance. An example of such a standard is that for soy macaroni products where the wheat interests pushed through a standard where soy flour had to be added at such a high level that a satisfactory, generally acceptable product could not be produced. A lower level

of soy flour would give improved protein quality in macaroni products, would permit the manufacture of an acceptable product, and would permit the consumer to get a better nutritional product more economically.

Since the establishment of standards of identity for many of our staple foods, new food additives have been developed which, when added to standard foods, result in improvement of these foods from the standpoint of both the consumer and manufacturer. Through petition many of these additives are now included as optional ingredients in the standards of identity.

In many cases, standards of identity and regulations were based on the best information available at the time, even though the political pressure of the special interest groups was always there forcing our bureaucrats to yield to these pressures even though their conscience might indicate a different approach or direction.

There is no question that the consumer should be protected from the possibilities of being cheated by unscrupulous food manufacturers, which would undoubtedly exist to some extent if our food laws did not exist.

On the other hand, the general public is generally not capable of selecting foods from the standpoint of value received from a nutritional standpoint and does need protection and education in this regard.

We all know that protein quality of white bread can be improved by the addition of protein containing sufficient lysine and with a reasonable balance of the other essential and nonessential amino acids . So on a common sense basis it would appear that products such as soy flour, soy protein concentrates or isolated proteins should be permitted in bread as long as the baker can produce and sell a loaf that is acceptable to the consumer, giving the consumer more value for his money. This certainly is not cheating the consumer and, from a practical nutritional standpoint, without regard to the interest of special interest groups, should be allowed without concern as to whether it is called white bread, soy bread,or mixed protein bread.

In meat products, it is well established that soy protein and meat proteins are essentially of equal quality. Again, we have standards of identity which, from a nutritional standpoint, are not realistic. Actually, there is evidence that proper combinations of soy and meat proteins may be somewhat improved from a protein-quality standpoint. If soy protein-containing products were added to comminuted meat products, at reasonable levels, the consumer would not be cheated from the standpoint of nutrition, the cost of such meat products could be lowered and the consumer would get more for his money.

In either bread or meat, the amount of soy which could be added will generally be controlled by consumer acceptance, but certainly reasonable controls could be put on by government regulatory agencies, if it were deemed necessary.

There are no official government records as to the production of soy flour and grit products in the United States. Most producers of soy products keep their sales information confidential, so it is difficult to make any accurate statements as to the utilization of the various types of soy protein-containing products in foods in the United States. During the past year or so, there appears to have been an increased usage of soy flour, which has undoubtedly been influenced by the high prices of nonfat milk solids. The present sale of soy flour and grit products for edible purposes is estimated to be at the rate of 275 to 300 million pounds per year. Recently, there has been an increased usage of soy flour in products produced for distribution by governmental agencies overseas. It has been estimated that the usage in England may be as much as 40 million pounds per year, nearly all of which is used in bakery products.

In the United States, the largest use of soy flour products is in baked goods, where its primary use is not for nutritional purposes, but to take advantage of certain physical and chemical properties of the soy flours. Any nutritional value which may be imparted to the baked product is strictly incidental.

The second largest use of soy protein-containing products is in the processed meat industry. When the soy products are added to meat emulsions, this addition aids in emulsifying fat and in blending the total ingredient mix, so that the finished cooked product has better flavor, since flavoring agents are more thoroughly dispersed and juices are not lost during cooking.

In the baby food field the largest use of soy flour is in high protein cereal products, where its primary use is to furnish good quality, low cost protein, but the physical and chemical characteristics of the flour are important in order to be able to produce a final product with satisfactory physical characteristics. As mentioned by others, some soy flour is used in soy milk products for feeding infants allergic to cow's milk. In human foods, the largest use of soy grit products is in the meat field, but the largest overall use for grit products, of the edible type, is in pet foods. Lesser amounts of soy flour and grit products are used in soup products, special dietary products, (both liquid and dry), macaroni products, pan grease formulations, dry breakfast cereals, breading formulations, confectionery products, artificial spice bases, certain fermentations, hydrolyzed vegetable proteins, etc. Another large use of edible type soy flour products, in the United States, is in calf milk replacers.

As mentioned earlier, one of the biggest stumbling blocks in the use of soy flour in food products has been the flavor characteristics of soy flour. In

many food products, soy flour with proper physical and chemical characteristics, and used at relatively low levels where flavor is not a problem, results in finished foods with improved characteristics over those without the addition of soy flour. In some cases, the more refined types of soy products, namely, isolated soy proteins and soy protein concentrates, can be used at considerably higher levels than soy flour, and have functional characteristics not possessed by soy flour, so that improved foods with more desirable eating characteristics, with markedly improved nutritional value and highly acceptable from a flavor standpoint are possible.

Those of us who have been associated with the specialty soy products area for 20 or more years are aware of the problems of marketing soy products to the food industry in the United States and the pitfalls that exist in introducing soy products into the foods of people in foreign lands.

In any government give-away program, great care should be taken to ship products of the very best flavor and physical characteristics possible within the realm of economic feasibility. If this is done, then the acceptance of products containing soy for use in their staple foods will be much easier in the future. As the level of usage of soy protein products increases, it is the hope that the countries using the product will eventually set up their own processing facilities and, where possible, grow their own beans.

It is unfortunate that when some of these government programs are decided, that opinions are not solicited from experts in the area of specialty soy products before proceeding with a program. It would seem that an expert civilian panel could be established to act as a disinterested advisory group to assist in minimizing problems which might arise in the future.

A case in point is the recent government purchases of a soy beverage product. The original soy beverage product formulation contained certain "cover up" flavors and was generally agreed to be quite acceptable. However, when bids were requested for a soy beverage product, it was not the same as that on which work was originally carried out. Although I hope we are wrong, many of us have doubts as to the acceptability of the product being shipped.

Unfortunately, from the standpoint of the government agencies concerned with the world feeding programs, the people involved in developing and administering such programs must yield to pressures of special interest groups, at least to some extent, to get some kind of a program underway. Perhaps a civilian board with no special ax to grind should be appointed to make the decision as to what should be used in these feeding programs so the harrassed administrators can do a more effective job, being free of political pressure.

As has been pointed out, when we speak of soy flour and grits, we are not speaking of one product but several different products. A soy flour with certain characteristics with regard to particle size and particle size

distribution, fat content, water dispersible protein, the rate and total amount of water absorption, etc., may give good results in one application and be entirely unsuitable in some other application. In some cases, enzymatic activity may be desirable and in other cases undesirable. In order to obtain desired results in any given application the soy flour must have the proper physical and functional characteristics.

It is usual to speak of isolated soy proteins and soy protein concentrates as if the product of every manufacturer were the same. Actually, the processes used by different manufacturers are such that the physical, chemical, functional and nutritional characteristics vary over a tremendous range. The differences are so great that in many cases in a given application, the product of one manufacturer may be quite satisfactory and that of another cannot be used interchangeably.

When papers are presented on the use of soy products in food preparations or in nutritional studies, great care should be taken to describe the characteristics of the type of soy products being used or else someone else, trying to duplicate such work, may have problems confirming another's results. Also, if an experimenter should unknowingly select the wrong product for his studies resulting in failure, publication of such results may give a completely erroneous picture as to what might be expected if the proper choice of product had been made.

Many manufacturers of soy products use trade names with certain designations which, in part, describe the characteristics of their flour and grits, but as the industry grows and the use of soy protein-containing products increases, it would seem desirable to develop some general standard system of nomenclature to more universally describe the various types of soy products, from the standpoint of their physical, functional, and chemical characteristics.

The types of soy flour products produced in other areas of the world are much more limited with regard to type and functional characteristics. For example, in England, up until recently, only the full-fat type was produced. Some soy flour products are also produced in Denmark, Germany, Israel, Colombia, South Africa, Brazil, and Japan.

Generally, the use of these soy flour products in foreign countries is limited pretty much to use in bread, with some use in meats, with minor amounts going for other uses such as ice cream in Japan.

To my knowledge, no facilities exist for commercial production of isolated soy proteins or soy protein concentrates outside the United States. Japanese workers have had pilot-plant quantities of a variety of soy protein-containing products, but I know of no commercial installations. An isolated soy protein plant is reportedly being built in Brazil.

Worldwide, there is a considerable commercial interest in all types of soy protein-containing products. A number of foreign companies are investigating the possibilities for markets for soy protein products with the view to eventual production in various countries.

With the exception of the traditional oriental soy foods, for practical purposes, the only large-scale production of specialty edible soy protein products is in the United States.

Soy protein products generally cannot be eaten directly but must be ingested as an ingredient in a more or less finished processed food product.

In the United States with our tremendous development of a massive volume of processed foods which require little or no home preparation, it is relatively easy to interest food manufacturers in using soy products if they offer some economic advantage or give a more desirable end product.

In many foreign countries, the processed food industries have not developed, as yet, to the degree that exists here. However, in many countries the rate of development of convenience and processed foods will increase greatly in the next few years, markedly extending the possibilities for the use of soy products produced in the United States and will create demand for facilities to produce soy protein products in other countries.

Some soy flour products, isolated soy proteins and soy protein concentrates are being exported from the United States, particularly to Europe and South Africa.

In some cases, the food laws, as they exist in Europe and some other countries, have restricted the use of soy products. In some countries, such as Germany, in the past few years some changes in the laws or interpretation of the laws now permit the use of soy flour in some processed foods. Some of these laws exist due to the same political pressures of special interest groups, but others exist due to lack of knowledge of the possible functional values of soy products in foods and the possible improvement of quality of foods from the standpoint of keeping properties, better physical characteristics, and nutrition.

Some countries, such as Mexico, although they recognize the food value of soy, restrict importation of soy products because the government is hoping to develop its own soy processing industry. It is reported that a government program is underway to fortify tortilla flour with about 6 percent soy flour.

In many countries, the types of foods being produced and the ingredients used are quite different from those available in the United States so it is not always possible to translate our technology directly to another country. In foreign lands it will be necessary for the technologists, who are acquainted with the available ingredients, food processing methods, and product

acceptability, to carry out development work to determine whether there is a place for some type of soy protein product in their food that give some advantage other than nutrition.

Another problem in some countries is the cost of shipping soy products from the United States and the duties that exist in some areas which, in some cases, may be extremely high.

Even though soy protein products are among the lowest price protein sources, and can be used to improve overall protein quality giving the consumers a better buy, nutritionally speaking, the consumer only considers the price per unit of what he is buying without consideration as to the best nutritional cost.

A wide variety of excellent soy products exist, as evidenced by the foods demonstrated at this meeting, which should somehow be used in some of the overseas programs. In the lower income areas there does exist a certain percentage of people who can afford some of the more exotic soy protein products and who would buy processed foods containing soy. If some acceptable foods containing soy could be introduced into these markets, it could pave the way for more broad use within these countries.

One approach which is being used is to introduce soy protein-containing foods into school lunch and clinic programs. If the right type of soy product can be introduced into their standard foods, or introduced in new economical acceptable food forms, working with home economists, nutritionists, medical people and technologists, this could be a big boost to developing their tastes for and knowledge of soy for possible future use on a broader scale.

Due to circumstances, most of the effort to interest people in soy has been carried out through the activities of scientists, economists, and technologists. In order to develop a real program, more use must be made of marketing and promotional people. It requires the efforts of a team with varied experience to plan and develop a truly successful program.

In the soybean field, the development of specialty soy protein products has been carried out by companies whose top management has had a commodity background and a commodity approach to selling. This remark is not intended as a criticism but as a fact of life. Marketing of specialty soy products into the consumer food field is quite a different operation from marketing commodities and has been quite a problem for those involved in pioneering the development, application, and marketing of these products. Fortunately, the management of many companies has begun to recognize this fact and with this recognition, greater strides are being made.

To some, it may seem the rate at which soy products have been accepted has been slow, but when one considers the number of years people have been eating, the development of interest in the use of soy products has really come along very rapidly.

With the changes taking place in our world economy, the increased demand for milk, production of which is actually decreasing on a world per capita basis, it seems only logical and necessary that there will be an ever increasing demand for soy and other vegetable protein products in the years ahead.

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PROBLEMS ASSOCIATED WITH MARKETING LOW COST SOY FOODS IN COLOMBIA

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Historically the United States Food Industry's product introduction in Latin America has been largely directed toward the upper income groups. Relatively little has been done to develop and introduce new high-protein foods to meet the requirements of low income groups. Yet, there are millions who fall into this category. Thus, this represents a fantastic potential for an industry which has the technical capacity to process foods to satisfy their needs and desires. However, it is not an easy task and we must begin by reconciling the fact that heavy underwriting will be necessary with slow return on capital investment.

The successful introduction of any new food product in Latin America requires proper integration of many factors. These, among others, include finance, marketing, manufacturing, purchasing, sales, advertising, and research.

It is the marketing approach, however, that provides the catalyst for turning the low income people's needs into demands. Our experience dictates that the best most useful product will not move in the market place without a carefully planned approach. The critical factors within the marketing program are as follows:

1. Product usage
2. Product nutrition
3. Price
4. Merchandising
5. Distribution systems

These factors will be discussed in relationship to our work with Incaparina in Colombia but we will use this only as a case example, and not with any pretense that this approach is the whole solution. There must be many approaches that can be used to solve the problem.

Product Usage

It is important to determine at the very start of the project if there is a strong food habit in the country in question. Emphasis must then be placed

on putting the product in a commonly used form, e. g., porridge, soups and gruels (colada in Colombia), drinks, and either cooked (colada or refresco) or fermented.

In the case of Incaparina for Colombia it was found that among the cereals there is a strong preference for corn. Based on this information, it was decided to formulate around corn flour specifically for use in coladas, which are regularly consumed by the low income groups. As a matter of fact, Latin American countries in general consume large amounts of cereals.

A product of the type described we term a "supplement." It is our opinion that the fortified staples and supplements are likely to be successful, because these products can be made in a variety of convenient forms to match local customs and habits.

Product Nutrition

In our culture when we think about protein, our thoughts immediately go to animal products, meat, milk, and eggs. Undoubtedly, animal products are ideally suited for meeting the protein needs of people throughout the world, but in Latin America they are extremely expensive.

Economics and tradition demand that much of the protein requirement be supplied by way of cereal grains. Their adequacy for this purpose is depicted in Fig. 1. This shows that after 4 to 6 years of age there is sufficient protein accompanying the caloric requirement as supplied by wheat, rice, or oats. The assumption is that they were the only foods consumed in adequate quantities to meet the caloric needs of the child. Our problem period, then, is mainly after the first year when the child has been weaned and before 4 to 6 years when a cereal diet is adequate.

Supplementation of the cereal diets, however, can make them adequate even during these early years. This can be done by supplementation with natural proteins, as is illustrated by Incaparina in Fig. 2 (1). Optimum gains are seen with these children between 18 months to 5 years of age when fed Incaparina at 2 to 3 g. of protein per kilogram of body weight per day. Similarly, if the cereal product is sufficiently high in protein to start with, as in the case of oats, amino acid supplementation will provide a sufficiently high quality protein to support nearly optimum weight gains even when providing only 1.5 g. of protein per kilogram of body weight. Oats must be supplemented with both lysine and threonine in order to achieve maximum response (2).

A third method of improving the basic cereal is by genetic alteration. Opaque No. 2 corn, which was discovered by Purdue University scientists to be unusually high in protein quality, provides maximum weight gains when fed to children at 2 g. of protein per kilogram of body weight (3, 4).

This data shows that by these three methods of supplementation, adequate protein quality can be obtained on cereal-based foods. It also points up the fact that approximately 2 g. of good quality protein per kilogram are required for optimum nitrogen retention. Children of this age, e.g. 18 months to 5 years, require about 80 to 100 calories of food energy per kilogram of body weight (5).

In designing a cereal-based food to supply protein for children of this age, there are a number of approaches which might be used.

Since we must recognize that some of the caloric intake for children of this age is probably going to be sugar, perhaps some fats and other low-protein materials, we think it is desirable that a product designed to meet most of the protein requirements contain at least 4 g. of good quality protein per 100 calories of food energy. Thus, a product that supplies only 50 percent of the calories that the child requires will still provide 2 g. of protein per kilogram of body weight. Such a product we have termed as "Fortified Staple" (6).

Actually, Incaparina contains about 7 g. of protein per 100 calories. At its 75 g. per day recommended intake, it supplies all of the protein requirements for a 2-year old child weighing 12 kg., but only about 25 percent of his required calories. It is also possible to formulate an even higher protein product which would supply fewer calories (10 percent or less), and we would term these to be "concentrates."

Although cereal-based products can supply the need of children, and probably will for the indefinite future, this does not mean that these people are going to become permanent vegetarians. Factually, all people like animal products and are going to demand them for a long time to come, as long as they have the wherewithal to pay for them. The history of our own society is to diminish cereal intake as our incomes increase. In the United States, we are now eating less than one-half the cereals and potatoes we ate in 1900 when our per capita GNP was about one-fourth of what it is today. It is reasonable to expect that the same change will develop in Latin American countries as their incomes increase (Fig. 3). This data shows that although the developing parts of the world will increase their cereal consumption with increasing incomes in contrast to the more wealthy areas, they uniformly show high coefficients of income elasticity for meat, milk, and eggs (7). Thus, we can anticipate that eventually they are going to demand high levels of animal products.

It is also interesting to note that meat, milk, and eggs are substantially preferred over fish. Many writers place great emphasis on the use of fish to solve the world protein needs and there is no doubt that they will make a tremendous contribution, but it does appear that given a choice people prefer meat.

Another significant comparison involving grams of protein which the Colombian consumer can purchase with 1 peso, equivalent to an American nickel, is as follows:

2.0 Grams of plantain flour
9.4 Grams of eggs
10.9 Grams of powdered milk
1.2 Grams of corn starch
78.6 Grams of Incaparina

These considerations lead us into a discussion of price, which we believe to be a critical element in marketing low-cost, protein-rich products in Latin America.

Price

One need not be an economist to guess that price is an important element in selling a protein-rich product to people in Latin America who have very little money. The American consumer spends relatively little of his income for food, he has the option of buying what he likes and, perhaps, what he thinks is good for him.

The average, or lower class, Latin American, however, spends a high proportion of his income on food and thus, tends to buy that which supplies his caloric needs most economically. This may mean that education directed toward nutritive needs may ultimately build a demand for proteinaceous foods. If we accept the principle that man will buy first to satisfy his caloric needs or "belly filling foods," and will purchase other nutritive needs only as he can afford them, then we can reason that further development of animal agriculture on the same kind of cost structure that now exists will not solve the protein problem unless the income of the Latin Americans rises substantially.

We were impressed, however, by statistics regarding the consumption of various products in our Latin American population in relation to their price. By plotting data in several ways, it was found that we obtained the best fit to the data if we plotted the amount of consumption in relation to the cost per unit of calories (6) (Fig. 4). It appeared to us that products with high protein achieved little or no premium and that this population was primarily buying food on the basis of its caloric content. Hence, it was concluded that to price Incaparina properly in order to achieve significant volume, we should have it no higher in price than the secondary staple, which in most Latin American countries is rice.

This price put us at or under other manufactured foods which were sold in considerable volume. This is dramatically shown in terms of their physical serving function as follows:

1	Glass of powdered milk	U.S. 5 cents
50	Grams of beans	U.S. 1-1/2 cents
50	Grams of Rice	U.S. 1 cent
1	Glass of Incaparina	U.S. 1/3 cent

With this kind of pricing in Colombia, we were able to gain significant volume. On the other hand, in Venezuela it was necessary for a variety of reasons to price above corn flour and some other manufactured products on a price per kilo basis. Thus, our test market results in Venezuela have been disappointing. This gives support to the original supposition that protein-rich products are very sensitive to price. To promote a premium priced high protein food via education and advertising is likely to be extremely costly.

Merchandising

The merchandising approach for Incaparina emphasized the before and after story shown in Fig. 5. This has been particularly effective in view of the background of clinical data, which we have on Incaparina from the work at INCAP and other locations. Radio has been an effective means of communicating an advertising message in Colombia. As a matter of fact, this medium is an effective and relatively inexpensive communication in most Latin American countries.

The packaging aspect of merchandising Incaparina was a critical factor to permit the low price. It was commonplace for retailers in Colombia to repack some bulk products in 500-gram bags. Thus, to reduce our packaging costs it was decided to pack in 35 kilo and 12 kilo multiple-ply kraft bags. Into each bag were placed, separately from the product, sufficient empty printed 500-gram paper bags for repacking of the product in the retail stores.

Distribution

In Colombia, we have used health centers as well as normal retail channels and have found this to be an effective means of distribution to the lower income groups, as shown in Table 1.

Table 1.--Where 219 users buy Incaparina

Montnly income (pesos)	Number of interviews	Retail outlets (pct.)	Health centers (pct.)	Gift (pct.)	Don't know (pct.)
2000 +	18	94.4	5.6	0	0
1000 +	45	88.9	4.4	0	6.7
1000 -	156	71.2	24.4	0.6	3.8

The question is, "How effective have we been in getting product to people who need it?" Our Cali test market data indicates that we are reaching 35 percent of the lower income levels (Table 2). At the same time, it appears that it is primarily the younger age groups who are consuming the product (Table 3). As a result of our test marketing effort and its results, we moved national in Colombia with the product about 2 years ago. We have not reached the same level of penetration nationally, but volume is currently running about 50 percent ahead of a year ago and is still climbing. It is interesting to note that in the first 4 months of this year, we sold the equivalent amount of protein which would have been provided by 5 million glasses of milk monthly in a Colombian population of some 15 million.

Table 2.--Survey of 700 families by income class as users of Incaparina

Monthly income (pesos)	Number of interviews	Percent users	Percent nonusers
2000 +	100	15.0	85
1000 +	200	20.0	80
1000 -	400	35.5	64

Table 3.--Data on age groups using Incaparina

Monthly income (pesos)	Number of interviews	Babies (pct.)	Children (pct.)	Adults (pct.)
2000 +	35	11.5	45.7	42.8
1000 +	76	5.3	52.6	42.1
1000 -	131	10.9	49.1	38.8

In conclusion, we believe that marketing a low-cost, protein-rich, cereal-based food to the classes in Latin America who really need such a product, can be an economically viable venture. It requires planning, hard work, persistence, and willingness to accept a long term payout. The best marketing approach for a given country must be determined since the same pattern does not work universally. However, from experience we will verify the fact that the task is worth the effort in terms of future markets, and it is a job which must be done in order to minimize malnutrition in Latin America.

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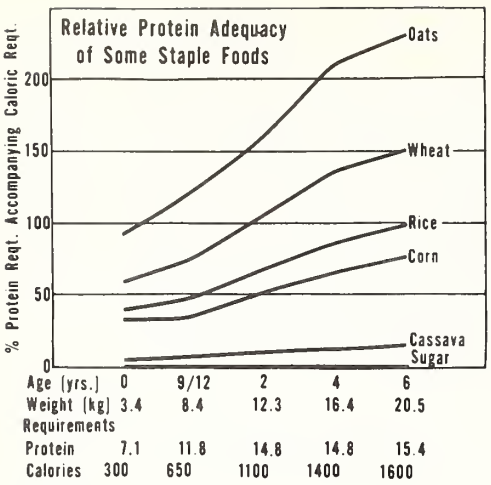

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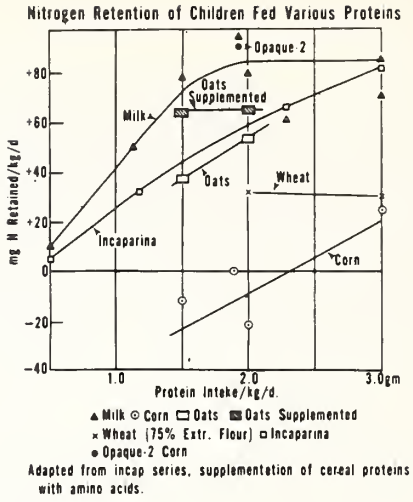

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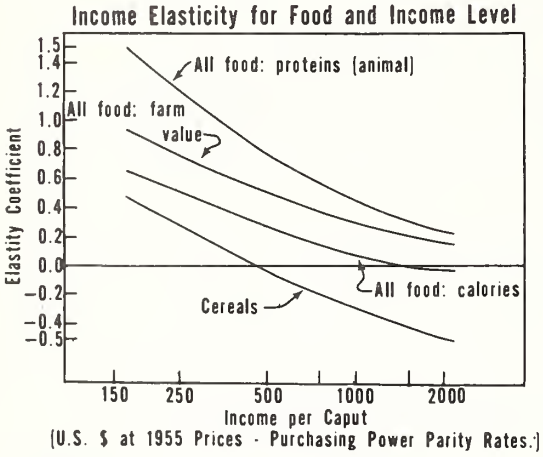

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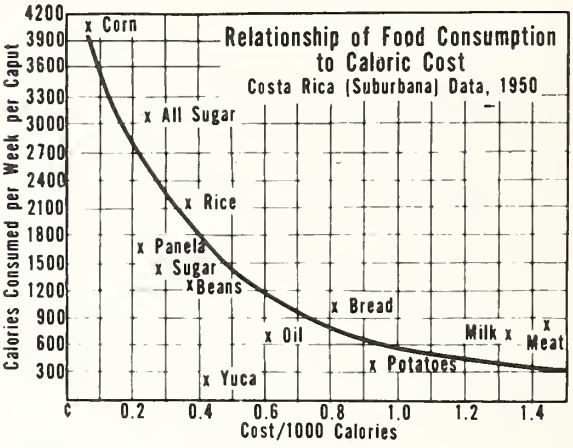

Figure 4.

Figure 5.

POTENTIALS IN MARKETING OF SOY FOODS

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The positioning of this paper, the "Potentials in Marketing of Soy Foods," is illustrative of the role of marketing in the world where we would promote soy protein products.

We have spent the better part of 2 days producing our raw material, developing our product ideas, and doing research as to where it's needed and why. We have ascertained what problems will be associated with its preparation and utilization and finally, we have had it manufactured.

We now come to the point which faces every management that has ever produced a product. Management can have comprehensive research, adequate production facilities, and a fine product; but there can be no ultimate fruition until the marketing team can persuade the consumer to use the product initially and then use it often. It is not one consumer in package goods; it must be millions of consumers and it must be done profitably.

The marketing process is neither easy nor inexpensive. The process by which a food marketing team coordinates the work of the scientist and technologist with the many factors involved in any food process is extremely complicated. Factors involved include selecting the right package, right in design, weight, color--and having it placed in the right outer container adequately prepared for transportation by land--train or truck--sea or air--into the channels of distribution in the right quantities to the right places so that there is adequate supply along the entire channel of distribution from the wholesaler to the retailer to the ultimate user. While simultaneously encouraging the movement of these products by his own sales force or his agents; while providing adequate encouragement to those wholesalers and retailers; and while maintaining a constant barrage of sales propaganda through both the printed media, be it in the form of newspaper or magazine ads, and the electronic media of radio and television, to say nothing of the auxiliary media as billboards in order to convince the public, the team should already have determined the market to be pursued. Whether you seek the young or the old, male or female, the married or the single or whatever is your audience, and never forgetting what the competition is doing; such a program is complicated and expensive and one doesn't do this unless there is plenty of potential.

What do we mean by the potential in soy foods? Is it the dollar profit? With very few exceptions, we haven't had much evidence that high protein soy foods are profitable. For everyone who has made a dollar in this area, many have lost funds.

Are we talking about the potential in relationship to peace? Secretary McNamara in his Montreal speech last May stated rather well that there can be no peace without security, and no security without development. I don't have to prove to this audience there can be no development unless we first eliminate hungry mouths.

What about overall international economic potential? Walt Rostow, Ted Schultz, and others have adequately documented the positive end results when we turn hungry mouths into economically viable hands.

What about the potential peace of mind and soul we might have when we know that the kids born in that other two-thirds of the world have as much chance to a laugh as our own do?

Peace, international economic vitality, and human decency are all part of the potential of marketing soy foods, but there's still more to it.

The real potential in the marketing of soy foods will be the knowledge we have accrued as a result of this continuing experience.

One of the chief reasons for corporate expansion and merger in this country has been the realization by a given management that it would know how to market a new or another product better than others. They understand that marketing systems can be learned and mastered.

This isn't so when we go abroad and, for that matter, firms local in given countries have difficulty appreciating this. If we can somehow break through this period of marketing when for Americans everything off our shore, especially in the developing nations is foreign, and if somehow we can transmit to our friends who themselves are processors abroad that marketing is based on principles which can be learned and adapted--we're going to see some food enterprises develop which will be as unlike our present food corporations as Westinghouse today is the Westinghouse of Air Brake fame.

When we do this, those firms who have mastered the marketing principles involved in the promotion and distribution of soy protein products will have a lead, which will place them in the driver's seat towards legitimate expansion and vast and legitimate profits.

It will be no mean feat to master the marketing techniques involved in soy products in developing countries. A marketing victory will be achieved in this field only when and if the marketing men involved produce a miracle similar to the one which the scientist and technologist produced when soy products became a reality. Consider for example, the frustration which occurs when in the United States a vast industrial complex decides to produce a consumer product. These firms soon learn that it is a great deal more difficult than they have assumed to master the rules which dominate the

channels of distribution, especially while serving the consumer. They learn that the consumer sometimes says "no"; more often nothing; and most infrequently "yes" to the product which their product development laboratory had said was just what that consumer needed.

Or consider the package goods oriented firm with years of studying consumer needs and wants in a given area. As often as not, products which this firm would introduce turn out to be unsuccessful. As likely as not, it is marketing method which is inappropriate and not the product. The specialists in charge of marketing are the first to realize that they can never be positive about which products and methods will succeed.

Recall too that these market specialists have available to them other professionals, both within and outside their firms, in such fields as market research, advertising, packaging, distribution, and so on. Each of these in turn relies on the best counsel available to make sure the involved product becomes one of those which can survive long enough to warrant mass production.

If it is difficult enough to do all these things in an area already well defined, with a consumer whose wants are fairly well known, what type of burden and what risk are we putting on the marketing man who must work outside of his own culture (and we must since some 90 odd percent of all marketing men are American oriented), where so little is known about the consumer; where the channels of distribution are at best ill defined; where he can't make any assumptions at all about the ability to produce the raw material much less process it, and prepare it for the market; where advertising and promotion methods are most primitive when pointed at the consumer he is most concerned with; and where he must think not only of his usual responsibility but also be conscious of foreign exchange and foreign policy, of confusing laws and regulations, and of habits and customs at governmental, trade, and consumer levels so different from his?

In spite of my concern, I'm convinced that here the ends most certainly justify the means and that the crown is worthy of the race.

It is axiomatic that the greater the risk the greater the profit must be. I know of no field which holds both the risk but also the potential in terms of peace, economic stability, human satisfaction, and finally of profit than in the potential of marketing soy products for the children of the world who are and will be the brothers of your children and mine.

In conclusion, while promising no quick dollar profits to those companies that involve themselves with soy product processing and marketing, I think they will be like, as the Psalms say:

> "Those that sow in tears shall reap rejoicing. Although tney go forth weeping, carrying the seed to be sown, they shall come back rejoicing, carrying their sheaves."

ROLE OF THE UNITED NATIONS IN THE INDUSTRIAL ADVANCEMENT OF DEVELOPING COUNTRIES

Bharatan Thiagarajan
Industrial Development Officer
Center for Industrial Development of the United Nations
United Nations, N. Y.

We in the United Nations are intensely interested in food technology; however, my object in addressing you is not so much the technological aspect, or to talk about the soybean, I am here to talk about the United Nations. Of course, some of you may regard the United Nations as just one great big soybean itself. Perhaps it may be necessary to eliminate from this great big soybean all its trypsin inhibitor factors, its hemagglutinin, its bitter principles, and make the most of what is left, the protein isolates, and the synthetic fiber, of which we had the pleasure of consuming yesterday, and have appreciated so much. We are coming to the end of a very crowded program and Dr. Milner has warned me that I must not take up much time. As most of you are aware, the first 100 pages of a paper are always the worst, so perhaps you will permit me to skip those 100 pages and get straight to the meat of the subject. I mean, of course, real meat and not those substitutes that we were eating yesterday. Furthermore, I am quite sure that in this country of yours, there is a tremendous awareness of the United Nations, and the role it has to play in the development of the world in all its aspects in the years to come.

More than any other organization in the whole world, the United Nations represents the crystallization of the hopes of humanity that sooner or later human beings will begin to behave like human beings and work towards a common end. We have already been quite successful in many things. As previous speakers at this gathering have indicated, especially Dr. O'Connor, it is very necessary that the "haves" of the world extend a helping hand to the "have nots," so that they become "haves" too, and then all can move forward in a common purpose towards the dignity of mankind which is so sadly wanting in the world today. I have a lot more to say about the United Nations, but time limitations will permit me only to refer, in passing to the fact that we are today celebrating United Nations Week. It was on October 24, 1945, that the Charter of the United Nations became law, witn the last signature that was needed. On this coming Monday, we shall be celebrating United Nations Day, the day on which the United Nations has come of age; it will be 21 years old on Monday, and I believe that it will be starting a new era in the development of humanity.

Dr. Johnson mentioned his surprise that real experts were not consulted more often in the problems that confront organizations such as the United

Nations, which are expected to carry a vast portfolio of problems and find solutions to them. We do indeed have such a program in the United Nations. The United Nations is composed of a very large family, including as one of its main organs the UNICEF, which is one of the sponsors of this gathering. In the United Nations itself, which you will see in New York, what will interest you most is probably the Center for Industrial Development. This branch of the United Nations started in a little way in 1962, about 4 years ago, as a very small organization. We have been feeling our way since then. Today, we have established about 105 professionals. On January 1, 1967, we intend to become autonomous and could greatly enlarge our activities. Our main purpose is to serve the interests of all countries of the United Nations of which there are 121 this week, with the addition of 2 new members, Botswana and Lesotho. We do not serve only the underdeveloped countries or the developing countries; we are there to serve the interests of the advanced countries as well; a point which is not often realized.

The program of industrial development is implemented through a series of channels, one of the channels being the recruitment of experts for the various countries of the world which may need expertise on their problems. In 1950, an Expanded Program of Technical Assistance was inaugurated, and at the moment it runs at about $35 million a year. This Expanded Program covers about 2,400 assignments each year with an expert staff of 1,500, and with fellowships (that means training of candidates) from the developing countries of about 1,300 per year. In 1958, the General Assembly of the United Nations established what is known as the Special Fund, which was created with the voluntary contributions of the member and nonmember states of the United Nations. During the 8 years of its existence, there have been 650 Special Fund projects, costing in all about $1,600 million. About 80 projects are already completed, about 380 are still continuing, and 150 are in the pipeline being processed. The rest have not yet matured. The Special Fund has recruited about 3,500 experts from various countries of which about 1,000 were recruited in 1965 alone. There have been about 28,000 counterpart staff (that means staff recruited and paid for by the countries themselves) to absorb the expertise of these technical experts who come from abroad, and to continue the program after the experts have left. In addition to all these, through the medium of the Special Fund, about 108,000 nationals have been trained in the various industries. The Expanded Program of Technical Assistance and the Special Fund have been merged from January 1, 1966, and at the moment the projection for this giant program is an expenditure of $200 million per year. About $180 million of this $200 million has already been subscribed for 1966 and the balance is expected in due course.

Another source of the wherewithal to implement this international program of technical assistance is the World Food Program. It is likely that representatives of the Food and Agriculture Organization will be able to tell you

more than I can. Nevertheless, I can say that this World Food Program comprises about $155 million of which about $120 million has already been earmarked and the balance of it is available for any other new project that may come up which is judged to be suitable for acceptance by the World Food Program. Incidentally, although it is called the World Food Program, it is not limited to projects which involve food production. It can be applied to any industrial project in which food needs are a means of implementation. Finally, there is in the United Nations what is known as the Special Industrial Services Fund, which is intended as a kind of crash program for relief in emergency cases where the normal programs of technical assistance would be too slow or not effective enough. We have at the moment about $10 million in the fund for quick and speedy relief in any industry around the world which may stand urgently in need of technical assistance.

Because you are in the United States and as most of my audience here are citizens of this great country, permit me to refer to one other source of funds, and that is the funds which are the biggest in the world. I refer to the counterpart funds held by the U. S. Government in many countries around the world, which have accummulated under U.S. Public Law 480. Speaking subject to correction, I believe that the total amount of money which the U.S. Government holds around the world is of the order of $10 to $12 billions, and in a country like India, for instance, I believe there were nearly $3 billion available for expenditure till today. One main obstacle in the application of these funds is the fact that many of the projects that have been suggested demand a certain amount of expenditure of dollars to make the scheme or the project viable. You cannot implement some of these projects entirely with local resources; you need a certain amount of foreign money, and this foreign money is just not available. Even a few thousand dollars, a few hundred dollars, a few dollars are not forthcoming in many of these countries, and for want of those little lubricants the entire money has to remain idle for the time being. It should not be too much of a problem to devise large-scale projects which make no demands for dollars, and such projects are certain to be considered favorably. There are, of course, many other reasons why these P.L. 480 funds are not more fully utilized, but shortage of foreign exchange, mainly shortage of dollars, remains the principal obstacle.

As an illustration of the interdependence of various sciences, I would like to refer to the utilization of agricultural residues for the manufacture of furfural, something in which the Quaker Oats Company has been the pioneering firm for the last 50 years or so. They have shown that it is perfectly possible to manufacture lysine from furfural. One of their chief technical men, Mr. Dunlop, has stated that the large-scale manufacture of synthetic lysine from furfural only awaits a demand for it. There is no technological or administrative problem that stands in the way of producing this lysine. Speaker after speaker from this rostrum has referred to the need for fortification of nutritionally weak diets with lysine. Assuming that

synthetic lysine is nutritionally equivalent to natural lysine, or can be made so, here is a great opportunity to kill several birds with one stone. Poor countries need lysine in large quantities, and if they have one material available, it is agricultural and forestry residues, completely adequate for the production of all the lysine they could possibly consume. Modern technology has succeeded in evolving plants and equipment which could be largely fabricated within the developing countries themselves. Incidentally, it may be mentioned that furfural could also be an important source of other nutritionally valuable substances like, for example, glutamic acid, adipic acid, butyric acid, and their derivatives.

Until now, I have spoken in generalities. Permit me to mention one specific possibility. In front of this podium, I see representatives from several of the great corporations of America. Would it not be possible for one of them to take up a substantial block of land in some developing country and make an efficient commercial farm out of it? A single block of, say, 10,000 or 20,000 acres of land is quite likely to attract a large corporation as a starting point. Money need not be a great problem as I have already indicated in this talk. Labor, of course, is no problem at all. Soybeans could be the principal crop on this farm with subsequent industrial processing to oil, protein, soybean milk, yogurt, curd, cheese, infant food, stock feed, and many other products. If the economics permit, industrial goods could also be produced, such as plywood adhesives, cutlery handles, and the like. Many of the developing countries have now gained excellent experience in the development of agricultural colonies, and I feel sure that any corporation which enters upon a project of this nature could not merely find the money from within the country's resources but also the expertise which would make these large farms economically attractive and profitable.

There are several industrial development projects which were started in 1962 in a small way, as I have said. Today, we have a substantial organization, and we are quite prepared to do all that is needed to make such projects successful. The present state of industrial activity in the developing countries covers a very wide range. There are several countries at one extreme, like for instance Burundi, Chad, Malawi, the Maldive Islands, Niger, etc., where industries are few and far between. At the other extreme, you find countries like Argentina, Brazil, China, India, Mexico, Pakistan, United Arab Republic, Yugoslavia, etc., with a well-developed pattern of advanced modern industries, including atomic energy power plants, iron smelting, steel manufacture, ship-building, petrochemicals, etc. In between these two extremes, the whole spectrum of industrial productivity exists. The need for technical assistance, therefore, follows the same pattern. For the limited needs of little countries, the expert would have to be the practical craftsman, pioneer, and innovator, who would have to play it by ear as he goes along, and do a good deal of the teaching of the authorities themselves. The industries to be established would be of the simpler type, generally to supply a limited local market or to upgrade the value of a product hitherto exported in its natural state. Power, equipment, and materials are simple, and buyers are often surprisingly discriminating, and price-conscious to a

disconcerting extent. There are other countries which are much more sophisticated and where only the latest techniques and technologies will be satisfactory. There are several American businessmen who feel that they could find industrial opportunities abroad. Naturally, they work for their own private profit but that does not matter, so long as part of the profit goes to the countries themselves. You will probably find that in these larger industries they will have a very great opportunity in the near future for establishment of new industries, and that is the message that I would like to bring you from the United Nations today.

GPO 803-663-15

PROGRAM FOR FURTHERING THE PRODUCTION OF SOYBEANS IN INDIA BY THE UNIVERSITY OF ILLINOIS

R. T. Milner
Head, Department of Food Science
University of Illinois, Urbana, Illinois

I should explain that for many years the University of Illinois has been interested in helping establish two universities in India. These universities are a departure from the previous type of educational institutions in India inasmuch as they are being modeled after the land-grant colleges of the United States. At Pant Nagar, which is in Northern India, State of Uttar Pradesh, the Uttar Pradesh Agricultural College is being built from the ground up on something like 15,000 acres cleared from the jungle. This is a new university which we are establishing and, as I said, it is modeled after American land-grant universities. The characteristics of our land-grant universities are the combination of teaching, research, and extension in one interrelated unit, each contributing to the other. This is an entirely American idea, one that I don't think can be found anywhere else in the world.

At the J. Nehru Agricultural University at Jabalpur in the State of Madhya Pradesh, we have an established university. It was started when the British were in India, and is being transformed into a land-grant type of college. We have been there for many years; members of our staff have served there for years and have come back. One of these men came forth with the idea, about 2 years ago I believe, that with these universities now established and growing, it would be well if we could give them an example of a problem which would not only benefit the university but would benefit the country of India as a whole. We thought that since we at the University of Illinois have worked with soybeans for a long time, the study of the potential of soybeans as a major crop in India was a problem worthy of attention. We have made a proposal to AID that is now being considered. I should point out that most of the details of this plan were worked out and proposed in India; have been approved by the Indian government; and are now awaiting approval at AID.

Our thought in conducting this work, if it is approved, is that we are going to draw on the experience of this country in the development of soybeans as a major crop. My own experience dates from the start of the Regional Soybean Laboratory at Urbana in 1936, and I can assure you that when I went there I found people at the university and in the government equally enthusiastic. Our thought is that if we can develop the same kind of background, the same kind of enthusiasm, and the same kind of cooperation among the universities, industry, and the government that prevailed to my personal knowledge from 1936 on, we can at least give soybeans a good chance of developing in India. I think that one of the things that we will try to do is

to develop fanatics, if you want to call them that, such as W. J. Morse, E. F. "Soybean" Johnson, and W. L. Burlison, to name three that come to mind from those early days, to push all aspects and to work together in developing the potentialities of this crop. In anticipation, I hope that something like this will occur. We have already asked some of our agronomists at these two locations to test out some soybeans as a crop in India.

Soybeans have been tried in India before with varying success, but there has been no concerted effort. There has been no cooperation among groups. Various missionaries in India have written back for samples of soybeans and have grown them in hit-or-miss fashion, but we can apply, it seems to me, the knowledge that we have gained ourselves over the years: uniform test nurseries, the cooperation between plant pathologists, geneticists, agronomists, and soils experts that led to our success. In India, we can bring teams like this together composed of Indians and show them how to operate. Our role in this is going to be that of advisor-participants. We are going to suggest things based on our experience. But the work will be done in India and the success will depend, I think, on our ability to get people with the same enthusiasm and capabilities that some of the pioneers had in this country.

As I have said, we have sent them some soybean samples. On the basis of a 1-year trial, there seems no doubt that soybeans can be grown in India and a good yield can be achieved. We are not deluded by this first initial success because we know that there are problems from predators, from pests, and from diseases with which we are not yet familiar. We are very conscious of the fact that marketing is going to be a tremendous problem. I might say that in our proposal the first people we shall send over there are equally divided between agronomists and agricultural economists. What our success will be, we don't know, but we feel that this is a sort of sure fire proposition because even if it turns out that soybeans are unable to compete successfully with peanuts or with some of the pulses that the Indians now grow and use, nevertheless, we will show these universities an example of a way in which they can work for the good of their country.

POTENTIAL AND USE OF SOY PROTEIN FOR LOW-COST INFANT FOODS IN INDIA

Ronald A. Hill
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United Nations, New York

I think it would be better if I am specific and not general in my comments. I am accompanied to this meeting by a gentleman, Mr. V. H. Shah, who is the production manager of the Kaira Co-operative Milk Producers' Union, Limited at Anand, which is 270 miles north of Bombay. I recollect that a little more than 13 years ago I flew into Bombay, checked into the Taj Mahal Hotel, and before I had time to complete my shower, two of Mr. Shah's colleagues accompanied by Mr. Glan Davies, the UNICEF representative in India, were in my room to discuss the first UNICEF-assisted dairy project for India. At that time the Kaira Co-operative Union had a turnover, I think, of about $1-1/2 million a year. Today, they have a turnover of over $15 million a year. Mr. Shah and his colleagues now have in their Co-operative 110,000 members. They are collecting something over 200,000 liters of milk a day. They send some 80,000 or 90,000 liters down to Bombay; then turn the rest into milk powder, butter, cheese, and 3,000 tons a year of baby food. In addition, Mr. Shah manages a feed mixing plant that is operating at a level of about 200 tons a day. This was donated through Oxfam.

UNICEF has now received a request that a further project be considered with this Co-operative group. For simplicity this has been termed a weaning food project, and the idea is to produce a cereal-legume-milk mixture. Mr. Shah is over here at the present time examining certain products, and also ways in which they can be made in order that a project can be established that we anticipate will start at something like 1,000 tons a year and in 5 years build up to 6,000 tons. With all the skills that have been generated and extended in the Kaira Co-operative Union group over the past 13 years, we are hoping for the same kind of expansion with this new project as took place with the first. This development, which received UNICEF assistance in 1953 to the extent of about $150,000, has also served as an excellent pattern for similar projects in India and elsewhere.

The Anand group is situated next to an agricultural college. They have done many things in the agricultural field and the thought has been expressed that this might be a first point where we could start to incorporate some soya in this cereal-legume-milk mixture. Mr. Shah noted down the following things in a discussion the other day, that is, some of the ideal conditions which Anand offers: They have excellent relations with farmer members, and this can be used in the coming days to promote interest in soybean cultivation. The milk powder that they make can be used for the milk portion of the mixture. The marketing organization for the infant food that they already produce can be utilized. It is built around the name "Amul" that they have adopted and this trade name is now known throughout the length and breadth of India. Incidentally, it is a respected name in the field of milk products. The feed

factory run in conjunction with the Co-operative could of course be used for some of the byproducts. The farmer credit setup that they have could assist materially in the growing of a new crop such as soybeans. I have noted down, last of all, their ability to run a large undertaking. This is just one hopeful outlet in the coming days, for putting to use a lot of things that we have been hearing at this Conference about soybeans and, which the last speaker mentioned, particularly in relation to a program with the University of Illinois.

Finally, I would like to mention a point developed in one of the first papers. The thought was expressed that in many of these less developed countries, there are abundant supplies of locally grown pulses. It is true there are many varieties of pulses available in India that can be used alongside soya, but it is also recognized today that with increasing population, a tremendous production increase is required from the ground. Therefore, in relation to these pulses, if an additional one such as soya can be grown to serve the needs of coming generations, we should give it every consideration now, especially in view of the expansion achieved in soya technology in other parts of the world.

Banquet Address: CLOSING THE PROTEIN GAP

George L. Mehren
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Washington, D.C.

I am delighted to have the opportunity to join in your deliberations.

You have asked me to talk about the USDA program on protein-rich foods for the developing countries.

I think I can best begin by putting the program in the context of the world food situation as it exists today and as we expect it to be in some not too distant tomorrow.

The plain fact is that we are engaged in a program to develop high protein foods not as an end in itself but as a part--an extremely important part--of the total world food problem.

The greatest challenge the world is likely to face in the last one-third of this century is to produce enough food for a growing population, and, ideally, enough to wipe out widespread hunger.

Let us take a quick look at the background of this challenge. The United Nations estimates that world population in 1900 was about 1.6 billion. Since then, largely due to disease control, world population has doubled. It is now estimated at well over 3 billion. If current trends persist, another billion could be added within a fairly short time.

Most of this growth is occurring in the food-short developing countries of Asia, Africa, and Latin America. It is currently estimated that by 1970, 2.5 billion people will live in the less-developed countries. About 800 million, nearly one-third, will be in Communist Asia. Nearly 560 million, over one-fifth, will be in India.

Despite the rapid population growth, world food production since the late 1930's has more than kept pace up until this last year.

Even in the less-developed countries per capita food production has risen slightly. The net gain since the late 1930's, however, has been only about one-third of 1 percent per year--or about 8 percent for the entire period.

Since 1954, the less-developed world, excluding Communist China, has continued to forge ahead slowly in per capita food production. Thus last year, population appears to have outstripped production increases. The Far East showed a considerable increase during the latter part of the 1950's,

but little or no progress since. Per capita food production in Latin America has also risen substantially. In Africa and the Middle East, food output has advanced at about the same rate as population. There is no clear or compelling evidence with respect to current population-production relationships.

Why, then, is there so much anxiety over the world food situation? There are many reasons, among them (1) increased per capita demand for food, (2) declining world carryovers of wheat and rice, (3) a succession of poor crops in many of the Communist countries, along with a severe drought in India last year, and (4) in increasing awareness that hunger and economic deprivation constitute a threat to world peace and stability.

Finally, the pace of population growth in some developing regions has been increasing, thus adding to present and future pressure against food supplies.

1. Increased per capita demand has made food consumption in the less-developed countries rise faster than production.

In India, for example, prior to the 1965 drought, the rise in food production was greater than population growth. Between 1948 and 1962, the annual compound rate of increase in India's crop output averaged 3.1 percent.

But per capita income at constant prices rose about 20 percent in the past decade. While still very low, this larger income led to a significant increase in per capita demand for food.

2. To meet the demands of more people--and people with more income--India and the less-developed countries in general have become importers, instead of exporters, of grain. In 1934-38 the net grain exports of the less-developed regions averaged 11 million metric tons annually. In the year 1965-66, the net grain imports of these regions totaled over 30 million tons.

This has changed North America from a moderate grain exporter to the world's foremost grain merchant.

Some 30 years ago, the U.S., and Canada annually exported about 5 million metric tons of grain, net. This year they are exporting 12 times as much--60 million tons out of a world total of about 70 million tons. No single region has ever before provided so much of the world grain trade.

It has also led to a sharp reduction in world carryover supplies of wheat and rice.

With wheat exports soaring, carryover stocks of wheat in the major exporting countries fell from a burdensome and price-depressing total of nearly 59 million metric tons in 1961 to less than 31 million metric tons this year. They may fall to about 25.2 million next year.

World carryover of rice has dropped even more steeply. In 1955, rice carryover in major exporting countries was 1.8 million metric tons. In 1965, it was less than 300,000 tons.

3. The breakdown of China's Great Leap Forward, the frequent failure of Russia and the communist countries of East Europe to achieve their agricultural goals, and the sharp drop in India's grain crop caused by last year's severe drought have focused international attention on the world food problem. To help India, the grain exporting nations of the world have sent this year, or are sending, 11 million tons of food grains--mostly wheat--of which the United States is supplying 8 to 9 million tons.

4. Despite their slowly increasing per capita food production and their sharply rising imports, people in the less-developed countries have average diets far inferior to those in developed regions. This constitutes an increasing threat to world peace and stability.

New methods of communication--and transportation--have shrunk the world. Those who have little can look over the shoulders of those who have much. And those who have little want to earn their place at the table of plenty.

World Bank data class the nations of the world into four groups--rich, middle income, poor, and very poor. Among the 27 rich countries of the world--where average per capita income is $750 or more per year--there has been only one major internal upheaval since 1958. Among the 38 very poor nations--with average per capita incomes of $100 or less a year, 32 have experienced significant outbreaks since 1958. In fact, they have averaged two major outbreaks per country over that period.

Finally, the prospects for a population rise of another billion in the fairly near future has caused the world to recognize that to produce enough food to meet future demands constitutes a massive challenge.

We know that the average diet in the developing regions is far inferior to that enjoyed by people in the developed countries. It suffers both in quantity and in quality of food. We know that there is a great deal of malnutrition in the world--and that most of it is in the developing regions. It is estimated that in regions containing about 60 percent of the world's people the average diet is short on calories. The average diet in regions where between 50 and 60 percent of the world's people live is short on protein--a prime measure of food quality--and in regions where a good 50 percent live, the diet is low on fat.

We are concerned about increasing food quantity--calories--and we are especially concerned here at this meeting with raising food quality--proteins.

A protein deficiency, especially in young children, the sick, or pregnant and nursing mothers, can have dire consequences. Dr. Aaron Altschul, of our USDA Agricultural Research Service who was appointed earlier this year to spearhead efforts to develop new sources of protein foods, says:

"This problem is critical in areas of the world where the major source of calories is, for example, cassava or some sort of 'sweet water' or other food which has a low protein content.... The body needs proteins....This is especially serious for pre-school children. Their brains reach 90 percent of full weight before age 4. If they don't get enough protein in that critical period, the brain just never does develop properly."

There is cost in finding ways properly to nourish a child. But it is right and moral that a child should have opportunity to reach his full potential as an adult. On a lower level of human values, it is better economics to feed a child well than to try to repair the damage of malnutrition.

But why is protein lacking in such a large proportion of world diets? We know, of course, that most of the developing regions are too poor to convert feed and forage into animal proteins--meat, eggs, and milk--such as constitute so large a proportion of our own diets. On the other hand, the major oil-seeds--soybeans, peanuts, and cottonseed, with high protein content--are grown in all parts of the world. Yet they are processed for food to only a very limited extent. Why?

There seem to be two major reasons. First, the towns and villages in developing regions lack the necessary processing equipment. They can't afford expensive equipment and they don't have the know-how to develop inexpensive processes.

Second, people in the developing regions, as people everywhere, tend to eat what tastes good to them. They have not yet devised ways to incorporate these protein sources into foods that they enjoy eating.

About 2-1/2 years ago we began to work on this dual problem in the laboratories of our Agricultural Research Service. Using a considerable backlog of information accumulated over a period of more than 20 years, we set out to develop processes which would be cheap enough and simple enough to be applicable anywhere so that indigenous protein sources could become available for food. Second, we set out to develop information on food formulations, home preparation, and home use which would be applicable to the dietary patterns and economic status of people of different areas, countries, and cultures. Our objectives were to make protein available and attractive.

As you heard in this Conference, industry, too, is working on this problem of making attractive soy protein foods, and many promising products are under development.

We have enlisted the participation of trainees from the developing countries. Their participation is, and will be, needed both in the pursuit of our research here and in the operation of the new processes and use of the new products in their homelands.

We are also working with AID, the United Nations Children's Fund, and the food industry.

We have had some successes in production and in product development. We have had some failures, and we will have more in all likelihood. But we are progressing, and we see opportunity ahead of us.

Making Protein More Readily Available

We have developed a hand process for making soybean flour. You heard a description of this process at the morning session today. It is designed to fill the needs of small foreign villages where skilled labor, electricity, and other services are unavailable. It uses inexpensive and readily available equipment. It discards only the hulls and converts the soybeans to a nutritious full-fat flour.

The finished product contains over 40 percent protein and 20 percent fat. It can be used in beverages, soups, and various cooked dishes.

With simple equipment made from readily available materials, ARS estimates that five men can produce 300 pounds of soy flour in an 8-hour day--enough to supply half the daily requirement of protein for more than 1,600 adults.

This is a highly significant development--but it is only one part of a two-part job. We must also carry through the second part.

Making Protein More Attractive

Neither food availability nor knowledge of nutrition can be depended on to guide food choice wisely. The diets of our own teenagers offer proof enough of this. Pleasant taste, or acceptability, is the key. So we need to find ways of incorporating new food sources of protein into familiar foods or into good tasting new products that fit easily into local food use patterns and preferences.

We have been seeking basic formulas, food combinations, and preparation procedures for soy, peanut, and cottonseed flour that will be attractive to people in the developing regions. We want to get the maximum nutritional value that is compatible with acceptability--and this includes not only taste but simplicity of preparation and economy of cost.

We have made a good deal of progress--at least that's what we are told by foreign students at Howard University from Africa and other underdeveloped areas whom we have enlisted in testing acceptability of the food products. The opinions of these people are of great importance. We Americans are not the best judges of oriental-type foods for people whose tastes differ

from ours. For example, the Taiwanese like soy beverage without added flavor, while we prefer the more familiar ice cream parlor flavors.

In our experiments soy flour has been used in beverages, yeast breads, corn-bread, unleavened breads, noodles, gruels, stews, curries, sweetpotato-rice combinations, and many other food combinations. Many of these products rated good to excellent in acceptability.

Peanut flour used for formulas for chapatis, puris, yeast bread, and rolls could replace one-fifth to three-fifths of the wheat flour. Cookies with 60 percent peanut flour were excellent.

The most acute protein nutrition problem, as I have indicated, is in the infants and toddlers. Gruels and beverages with adequate protein are needed here. Cereal-soy-nonfat dry milk combinations supplemented with vitamins and minerals have been formulated which have good promise as gruels or porridges in child feeding. Indeed, the Department has recently purchased about 36 million pounds of such a product which was formulated by industry in accordance with guidelines developed by the USDA-AID committee on Food Processing in Developing Nations. This blend, containing about 20 percent protein, will be distributed by AID and the voluntary agencies to needy populations abroad.

Soy-based beverages can give children as much protein as milk. The essential amino acid building blocks for body tissues are present in quantity, as are the needed calories. The full-fat flours produced in the simplified processes that I mentioned earlier are promising as beverage bases. A soy beverage base developed by the soy industry has been purchased by the Department and is now undergoing acceptability tests in selected areas of developing countries.

In areas of the world where food is short in both quantity and quality, protein foods do not normally go mainly to the young children. But a beverage or gruel from a high protein, protective food such as soy flour could go a long way in supplementing the low protein, starchy cassava, yams, rice, corn, or other foods of these youngsters. If the soy replaced one-third of a cereal such as rice or corn, the protein contribution would be more than doubled, and it would be better protein as well.

The possibilities and opportunities are great. The need is real. Fortunately, the research to backstop action programs is well along.

There are other supplementation projects underway which if successful would involve no change whatever in the distribution or processing or utilization of foods now consumed.

We are also conducting research on protein crops for the developing countries to tailor plants and management practices to environmental conditions.

Moisture, temperature, day length, soil conditions, weeds, insects, diseases, and other factors must all be considered. Some plants have special limiting environmental requirements. Soybeans, for example, are very sensitive to the length of day, with the result that a given variety is generally adapted to a zone only about 150 miles wide from north to south.

The legumes have special interest as alternate protein sources to meat. But leguminous plants, such as soybeans, alfalfa, peas, and beans, need an appropriate bacterial population.

The difficulties of introducing crops into new areas or of substantially increasing productivity are many, but some successes have been achieved.

Some of the techniques used so successfully in the United States can and will be employed in the developing areas, in varying degrees, to step up food production and improve its quality. These include irrigation, drainage and reclamation programs, hybrid seeds and new plant strains, better tools, fertilizers, weed and pest controls, growth regulators, and so on.

But it is one thing to apply the tools and techniques of agricultural science in such technologically advanced countries as the United States and Japan. It is quite another thing to apply them in the developing nations.

We cannot do the job simply by sending U. S. materials--whether food, fertilizer, seed, pesticides, tractors, or warehouses.

What we must also give is people--people with the knowledge and background to take the things that America has learned and adapt them to new areas, untried soils, different climates, untrained farmers.

We are making progress here also--and President Johnson's new food aid program will help--but there is so very much to do.

During the past year, in cooperation with AID, we developed, supervised, and evaluated training programs for almost 5,000 technicians, students, officials and leaders from over 100 countries, including practically all the developing countries. We have been trying to teach others to teach. We are seeking a multiplier effect among our students.

Some 300 USDA technicians worked through AID-sponsored programs in 39 countries last year--an increase of about 50 percent in both personnel and countries over the preceding year. AID, I understand, has a substantial total of technicians carrying out agricultural programs in countries throughout the world.

As Secretary Freeman said recently, "When I look at these resources in the light of the immense job that must be done, I cannot help but see that our efforts are dwarfed by the need.

"But then when I recall again what this handful of experts is accomplishing, and supplement it by the knowledge that their numbers are going to grow in the years ahead, I take new heart."

There are hopeful signs that victory over hunger can indeed be won. Sharing of know-how and capital investment now planned in the developing nations is increasing. There is growing realization that enhanced agricultural capacity is crucial to development.

And when I look at the tremendous skills the developed world can or will be able to bring to bear on this problem--skills including atomic power--the computer--rapid transportation--modern communication--and present and coming breakthroughs in biological and physical science, including agricultural science--then indeed, I am convinced that victory over hunger can be won--and will be won.

The race is not really one between population and food supply. It is really a race between what could be done and what will be done.

SESSION V: ACTION, PANEL DISCUSSIONS, AND SUMMARY

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KEYS TO SUCCESSFUL MARKETING IN DEVELOPED COUNTRIES

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The subject of successful marketing in any area, developed or developing, is of course much too broad and complex for me to try to do more than touch on a few aspects of it largely within my own experience and observation.

When the phrase "markets in developed countries" is mentioned, it brings to mind first the great concentrations of people and buying power represented by Western Europe and Japan, which with Canada, make up the major part of the commercial export market for American food products.

It is these areas that presently hold the most potential for expansion of food sales in the years immediately ahead. One of the major reasons for this is that per capita incomes are relatively high and continue to increase. More and more people in these areas are progressing to income levels that afford a degree of choice in what foods they buy and the amounts they spend.

The keys to successful marketing are probably much the same everywhere, the major differences being those arising from differences between incomes and consumption habits; the latter, of course, being related to the make-up of nearby food production. However, as a general proposition, it is the areas which have arrived at a higher state of industrial development which we look to as more likely commercial markets for our food products, particularly processed foods.

This may be more true of food products generally than for soy food products. Developed markets are often so well supplied with a variety of products, and income factors are so relatively favorable that there are fewer supply or

income urgencies of the kind which facilitate the introduction and use of new products. This may mean that extensive familiarization and promotion efforts would be required in order to create sizable new markets in developed countries.

On the other hand, even though developing markets may not have the income, the nutritional needs of large numbers of people are far greater, so that with adaptation of soy food products to local conditions, these markets may actually offer more real commercial possibilities than the developed markets.

In naming the essential elements in successful marketing of foods abroad, I would begin with these:

1. Knowing the product, including its intrinsic composition, qualities and properties; nutritional and preference values; and how to move it through the marketing structure from production point to consumer.

2. Knowing the customer, including the conditions which govern the entry of the product at country borders; knowing the wants and needs of importers, distributors, processors, or consumers; and knowing the buying capabilities of consumers, their eating habits, and their taste and product preferences.

3. Knowing the competition, including the competition from similar products in the market.

In a large sense, our knowledge in the last two of these three areas is especially limited in the case of soy food products, simply because experience with them is so brief and localized. However, knowing the products and passing on to others what we know, and learning more about the customers we hope to sell to and the nature and degree of the competition which must be dealt with, should of itself provide many of the guidelines to successful marketing of these products.

It would also be a guide to the development of products which accommodate to the conditions which prevail in the market places around the world. In some cases, it will be easier and more effective to adapt a product to meet local conditions or taste preferences than to modify consumers' opinions and attitudes or food consumption habits.

In the effort to develop acceptable products, the versatility of soy foods should be a marked advantage. Few foods are adaptable to so many uses.

Some of the subjects which we need to know more about are these:

1. Does the fact that meat prices in many developed countries are quite high offer special marketing opportunities for soy food products as simulated meat or as meat extenders?

2. Would mass feeding operations facilitate the introduction and acceptance of soy foods? I have in mind particularly the feeding operations in industrial firms and school lunch programs that exist in many countries in which nutrition and cost considerations are especially important and which involve relatively substantial procurement.

3. Would nutrition experts be natural allies in gaining acceptance of soy food products and, if so, how can their interest and support be tapped?

The Foreign Agricultural Service (FAS) of the Department of Agriculture does a number of things aimed at creating a favorable marketing climate within which export business can be done.

The most essential is the day-in-day-out work by Attache staffs and in Washington to improve what we term "access" to foreign markets. This work is directed at improving the conditions governing entry of the product into foreign countries.

This includes the whole formidable array of government-imposed restrictions and regulations governing entry of products--tariffs, import taxes, levies, and charges of various kinds; restrictions on the volume of imports which some governments maintain; the inspection procedures and requirements pertaining to health and sanitation safeguards; and local laws and regulations relating to packaging, labelling, chemical additives or residues, and the like.

FAS maintains agricultural attache staffs in 60 locations, worldwide, covering more than a hundred countries. A large part of their work is involved in learning about and reporting on production, markets, government policies, competition and other matters which bear on the interests of American producers and exporters. But the main thrust of their work is in improving access conditions and otherwise expanding exports of American foods and agricultural products. Also, each year they assist many thousands of visiting American businessmen in becoming acquainted with the people and conditions in local markets.

FAS cooperates with 45 U.S. trade groups in actively promoting foreign markets. These include the Soybean Council of America and the American

Soybean Association. FAS's financial contribution to the foreign market development activities of these two groups through the end of the 1965 fiscal year amounted to more than $6 million and represented almost a fifth of total expenditures for such programs. Their activities have had an important role in the growth of export markets for soybean products.

FAS carries out an extensive program of participating in trade fairs abroad which offer opportunities for exhibiting and testing products and for trade contacts.

Also, in cooperation with the Department of Commerce, FAS maintains permanent trade centers in London, Milan, and Tokyo which feature exhibitions of commodities and carry out various other activities to expand sales opportunities.

These trade fair and trade center activities offer good opportunities for acquainting people abroad with new food products, and for obtaining trade and consumer reactions to them.

The relatively short export history of the soybean and its products has been an impressive one. Ten years ago--in 1955-56--the value of exports of soybean products was about 260 million dollars. Last year--in 1965-66--it amounted to more than a billion dollars.

In contrast to this growth of commercial export sales of soybean products as a whole, in a volume sense soy food products have only arrived at the threshold of the export market.

With more widespread knowledge of these products, more awareness of the nature of export markets and of consumers abroad, and application of this knowledge to product development and marketing efforts, I see no reason why soy food products could not achieve an important place in commercial trade.

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THE WAY FOR ACTION PROGRAMS IN DEVELOPING COUNTRIES

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The title assigned me, "The Way for Action Programs in Developing Countries" includes two thoughts. One is "the way for action" and the words "in developing countries" can be omitted because "the way for action" is basically the same in developing countries as in a developed country. The other thought in the title is "action programs in developing countries." Let us consider this part of the title as it relates to the food assistance program and the war on hunger.

But first, to go back to the "way for action," from my own observation the primary requisite for action is technology and techniques based on research and scholarship. That base is needed before you start action programs. Also required is awareness of the need for a program of action. I started work in the Government in the depression-born Agricultural Adjustment Administration so when I am looking for an alphabetical device to describe something I use the three A's whenever I can.

To get action in the United States or anywhere in the world, you need three forces moving. The First A--is altruism--the humanitarian urge _ Assistant Secretary Mehren talked about so eloquently last night--it should be done because it is right--the moral imperative--is the first force for action. The Second A--in terms of U.S. action, is "anticommunism." I use anticommunism as an oversimplified term to encompass the whole scope of that which motivates political action. This brackets attitudes all the way from the very conservative to the very liberal. There is a wide area of agreement that underlies both foreign and domestic policy as to what we need to do to advance our overriding objective which is to live in a world dedicated to peace and progress. The Third A is advantage--economic, or other advantage to the producers of the commodities, the railroads, the ports, the ocean shipping lines--the whole private enterprise complex.

How do these three forces organize to produce action? The political, the altruistic and the economic forces can't be put in one package. But the altruistic and the political forces can be combined and the political and the economic advantage forces can be joined. When these two combinations of forces are moving on a concurrent time scale and in approximately the same direction, action programs follow.

The Food for Peace Act of 1966 now in the final stage of the legislative process is an outstanding example of these combinations of forces. This Act,

in addition to eliminating the label of surplus and starting from the deliberate plan to produce food to meet the need for food assistance, authorizes an increase in the level of food aid. With only 2 adverse votes in the Senate and 20 in the House, the Congress has approved the production and use of up to $2-1/2 billion of food per year for this purpose.

Let us try to put the food assistance program into the broader context of the total assistance efforts of the United States and other developed countries. Thankfully, it is increasingly appropriate to say the total activities of the developed countries--still too largely on a bilateral basis--but the totality of the effort of the developed countries to do what they can to support development efforts within the developing countries.

First, the economic assistance aspects of the U.S. foreign aid program is about $2-1/4 billion annually. Of that $2-1/4 billion, about $300 to $400 million goes for the transference of "know how"--technical assistance. About $1.8 billion finances the transference on a concessional basis of nonfood material and equipment. The third part, the food assistance part--funded under the Food for Peace Program as part of the farm program--has been averaging about $1.6 billion.

The food transference takes two forms: First--sales on concessional terms--that is sales to a country that does not have the foreign exchange with which to import enough food to meet the requirements of people within the country who can buy it if it is available. In this case, the food moves through commercial channels and the markups at each point in the chain of distribution finance the management required to move it from the port to the market place and into the hands of the customer. This form of transference has been in the magnitude of $1.2 billion dollars per year.

The donation programs, the second form, have been averaging about $500 million. The donation programs represent the kind of action that is important not only from a humanitarian, but also from an economic development standpoint. The technology and techniques of vegetable protein are extremely important to the accomplishment of the basic objective of the donation programs. Of course, the first objective is to meet the immediate hunger needs of people who don't have the money to buy the food they need even when it is freely available.

We are at this time making donated food available to supply school lunch feeding programs all the way from highly sophisticated ones to a simple glass of milk and maybe a piece of bread to 40-1/2 million children in 91 countries. Hugh Robinson mentioned the possibility of using the school feeding programs to test and develop consumer acceptance. This is a deliberate part of our objective because just using the food to relieve the hunger of the day is not enough. It's fine, good, and humanitarian; but we can and should do much more.

The food habits in many countries of the world can be and have been changed. Japan is an early example of a country where we started a school feeding program and where they have long since graduated, and now "phased up" their own contribution to 100 percent and ours to zero. Japan is now a major commercial customer for our food. Mexico has another similar story. Italy has completed that process and has a nationwide school feeding program. Greece is in the next to the last year of completion of the "phase up" process. Our primary objective in the school feeding programs is to phase up the host country's input to the point where they can supply the food for their own school feeding program, 100 percent, either by producing it or purchasing it commercially.

In the case of Brazil, when we started 4 years ago, they had a school feeding program on paper but none in fact. The head of their school feeding program is visiting in the United States as is the head of the Food for Peace Division of the Commodity Credit Corporation of Brazil this week. Over 7 million of the 15 million Brazilian elementary school age children in Brazil are participating. Our goal calls for completion of that program in, I believe, 6 more years. When it started 4 years ago, the donated food from the United States was 95 percent of the input. The Brazilian local, federal, and state input was 5 percent. Today, the Brazilian input is up to between 30 and 40 percent and moving up at a sharply accelerating rate. Our objective, in other words, is to do more than get the children to go to school. The school attendance in Brazil goes from 20 to 30 percent of the age group without school feeding to 70 to 80 percent with school feeding.

The school children are the easiest group to reach and as I say, we are reaching 40-1/2 million school children not counting those that have graduated.

But the starter is what we are talking about today. How do you get things started and how do you seize the opportunities that are associated with what you are doing to make them better, to get more, to accomplish more? Let's shift a minute--Dr. Senti referred to the food for work programs. I like to think of food as energy and, I think, if we fail to help organize, utilize, and channel the energy the food provides into a constructive attack on the need for food that we are not doing enough. It has been our conscious objective and plan to convert relief feeding of the subsistence type into food supplied under organized conditions under which the energy is used to attack the cause of the need.

Let me back up and say that whereas in the concessional sales program, the markups provide the management for moving the food from the port on into the channels of consumption. In the case of the donated food, there are no markups--since the food is not sold. Therefore, the big problem is the management. The voluntary agencies, their local counterparts, the international agencies such as UNICEF, and the local governments at all levels

must supply management and the internal freight financing. Today over half of the adults receiving food under the donation program are receiving it as part of an organized activity attacking the cause of the need for the food.

We think a great success story is occurring in Korea. I don't know how many of you have been in Korea, but as you know South Korea had to absorb a great many people from North Korea. The mountains and hills of their country have been stripped of trees for many, many hundreds of years. With nothing but food and carefully planned, organized, and trained effort on the part of the Korean Government, they are bench-terracing those barren mountains of Korea. The workers receive food and conditional title to about 5 acres of the bench terraces they are building themselves. There is real basis for optimism that the need by Korea to import food on a concessional or donational basis will end--that within 3 to 5 years they will have completed the job and will probably be a net exporter of food.

There are some dramatic examples in other countries. In the Philippines, for example, the Catholic Relief Services, a large voluntary agency, work with the people receiving the food, pull in the rest of the townspeople and together they try to find out what the people think they need the most. Even though it may not be the most economically sound, if it is a useful project they go to work. In some communities in the Philippines one of the jobs the people are doing with food, and often with volunteers who don't need donated food, they are ditching and draining off the water that provides the host for the snail that carries the schistosomiasis germ which makes the land unuseable and the place unfit to live. By drainage, they make the area habitable and restore the land to production.

In Northeast Brazil, they are building literally thousands of kilometers of farm to market roads. The fundamental objective, in other words, is to do more than meet the humanitarian or political needs--it is to get something done for the future. In the case of the school lunch program, it is a deliberate effort to make it part of the social and political pattern of that country to feed their children one balanced meal at school each day.

We are keenly aware that from a health standpoint the problem is much greater in the group that is much harder to reach; the small children from the time they come off the breast until they are 5 or 6 years old. We are reaching some 10 million with the donated food--not nearly enough. We plan to try to expand this number. Here again we try to do more than attack the malnutrition which is the number one health problem in the world today. We think there are many advantages in terms of the right of human beings to make a choice about conception if mothers have occasion to come to public health centers. We don't tie the two together but we are going to try to accelerate and expand the use of the public health center.

In terms of seizing opportunities, Nevin Scrimshaw and George Parman went to India at AID's request in January 1966, to work on the "qualitative" aspects of the Indian food problem. They worked with Indian Government food scientists--India has some outstanding ones. They worked on the possible applications of the blended grain and oilseed protein concept. They also developed, with Indian officials, a name BAL AHAR--I use this as an example of what we hope to do worldwide--the word BAL in Hindi is an affectionate term for child and AHAR means nutritious food. It is our hope that the word BAL AHAR will become a generic name just as are the words milk and eggs. We hope the day will come when the major food companies will be selling their brand of BAL AHAR as a prestige food for children--as a prestige food that parents who really want to look after their children will pay the extra amount above the cost of the grain which is currently the diet of the child.

We see the corn-soya-milk mixture which is a very simple prototype of the sort of product we hope to see being sold the world over. We have two reasons for this: (1) In the long run, what this Government does in the way of supplying food to meet human needs abroad must be efficient and economical; and (2) we have too often in the years past taught people to drink milk and to want milk for their children who won't be able to afford milk for their own children. They need to learn to like and want to buy foods that are within their price reach that will fill approximately the same need as milk or eggs--and be within their purchasing capabilities.

The world need to utilize ways to meet the protein requirement without the inefficiency of using 3 to 6 pounds of grain to get 1 pound of meat, milk, or eggs.

Again, in the case of the corn-soy-milk (CSM) mixture, we hope to seize opportunity. We had hoped in the case of the blended foods to introduce them very gradually and concurrently with introduction of commercial production abroad of like products--using the school feeding program and the donation programs for familiarization and consumer acceptance. Because of the unavailability of adequate supplies of milk, we have had to step that up, and go first with the CSM and try to get what benefits we can in the way of obtaining the familiarization with this blended food concept.

We hope that a high-protein product can be developed that can be spread on that piece of bread to go along with a glass of powdered milk for the child in the school feeding program. We hope the industry will come up with a low priced nutritious tasty spread--at a price well below the price of meat, milk, or eggs. We also hope that something new can be developed--a slice product.

We think this is the direction the world must go. We think it is healthy; we think it is sound; and we think it is good. The affluent both here and abroad have every reason to lend their support to it. We have been thrilled with the way the food industry and chemical industry of the United States have been digging into this problem. We are greatly encouraged by the

increasing emphasis in the AID program toward reaching more directly at the needs of people.

It is a real pleasure to be here. The challenge I would throw out to you in closing is work, watch, support, and fight for opportunities to capitalize on what is already being done to make it better--to do more than meet the immediate needs. I think that there is increasingly, on the boards of directors of large corporations, a realization that while the balance sheet must be the first consideration, some consideration should be given to supporting efforts to promote a peaceful and progressive world so as to assure that there will be corporations for their children and grandchildren to manage.

Panel Discussion and Summary on Needs, Potentials, and Role of Soy
--LEONARD L. McKINNEY, Chairman

SUMMARY OF SESSION I ON POTENTIALS FOR SOYBEAN PRODUCTION AND USE AS RELATED TO WORLD PROTEIN NEEDS

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Protein Deficiencies and Needs

With respect to protein deficiencies and needs, as well as the possible role of soybean products, we heard from representatives of three large geographical areas: Latin America, Africa South of the Sahara, and South East Asia. Generally, per capita food availability figures indicate a problem with respect to both quantity and quality of protein. As far as young children are concerned, the problem is accentuated by the maldistribution of food within the family. There is conclusive evidence of a general pattern of a considerable incidence of acute protein-calorie malnutrition in young children in the form of kwashiorkor, in which protein deficiency predominates, or marasmus, in which undernutrition may or may not be complicated by inadequacy of the protein component of the diet. This is only the "top of the iceberg" and for every case of acute malnutrition there are dozens, or even hundreds, of children whose immediate and future health, physical development, and probably mental development, are jeopardized by malnutrition. Mortality rates are much higher in this age group than in the developed countries and it is clear that malnutrition is one of the most important (if not the most important) contributing factors. Pregnant and nursing women are also particularly vulnerable to malnutrition with deleterious effects on both mother and offspring.

One of the speakers suggested that it was really impossible to communicate through words--or pictures--the extent and nature of malnutrition problems. He said "It has to be seen directly to be believed." I might add that very often even if it is seen, the critical preventive role of nutrition, in combination with combat of infectious disease, is not fully appreciated. This perhaps should not be surprising when one considers that in many cases a mother must see at least two episodes of kwashiorkor in her own children before she is convinced that her feeding practices have some connection with her children's health. There was a hint of disappointment that, although a number of policy- and decision-makers in high places have shown a much greater sensitivity to nutrition problems in recent months, much time and energy must still be spent in convincing--and reconvincing--as to the importance of nutrition programs. The speaker can state with considerable confidence that this found a responsive chord in at least one member of the audience. I hasten to add, however, that it is fortunate that those who are not yet fully convinced continue to be willing to listen.

The three geographical areas about which we heard may be placed in somewhat different categories:

Latin America--In many countries of Latin America, officials have begun to give special attention to nutrition programs. Although, in most all cases, these are only small beginnings; in several instances they have included attempts to manufacture and distribute special supplementary foods based on vegetable protein concentrates.

Several countries in Latin America are fairly well advanced in production and processing of soybeans. Supplementary food mixtures, including soybean flour, have been tested at INCAP and defatted soybean flour is an ingredient of the Incaparina formulation sold in Colombia. Dr. Bressani brought us the interesting news of the encouraging preliminary results in soybean production trials in Guatemala which have been sponsored by cottonseed producers and processors who are concerned about the deteriorating economic situation with respect to cottonseed and are looking for an alternative oilseed.

Africa--As to Tropical Africa South of the Sahara, we heard that as yet there is not generally a severe population pressure on the land. In some climatic regions there are periodic famine conditions. In other areas, the traditional feeding of infants after breast feeding is based on high calorie, low protein gruels. Even the basic family diet often contains far too high a level of low protein tubers along with cereals with insufficient legumes or animal proteins to balance the diet. Newcomers to the urbanized areas often don't have the money to purchase the food they need for an adequate diet.

Soybeans are grown in some African countries, but so far mainly for export. Several countries, however, are showing an interest in developing local processing of soybeans, including production of edible protein concentrates.

South East Asia--In much of South East Asia, the pressure of population on land is already at a critical stage; and it does not seem to make sense to think of increasing food production without, at the same time, considering measures to assist families in planning the spacing of births and limiting the numbers of children in order to give them a reasonable chance for proper development. Protein malnutrition in South East Asia is commonly made more serious by accompanying deficiencies in calories, vitamin A, and riboflavin. There are serious limitations as to expansion of animal production. There is considerable scope, however, for increase in fisheries development, both off-shore and inland. In a number of countries, there is still too much concentration on cereal grain production without appropriate attention to the "protective foods," including certain vegetables or fruits, as well as animal protein foods, that could balance the diet.

Soybean food preparations have been used for centuries in parts of South East Asia, but efficiency of production and use of soybeans probably could be increased markedly. Countries not currently producing or using soybeans should consider the possibilities of introducing soybeans into their agriculture and food economies. In this connection, the University of Illinois/AID program in India has initiated soybean planting trials and is

prepared to expand and extend this work if that is desired by the government. In all three of the areas discussed, it was considered that special supplementary food mixtures suitable for young children ("weaning foods") could play an important role.

Potential Production

Currently the United States produces about 70 percent of the world's soybeans and Mainland China about 20 percent. The production in the United States probably will continue to increase, but it is possible that in the future a larger percentage of the world's supply will be produced in countries that now have little or no production. Government policies will have an influence on the rate and extent of this development, but ultimately competition with other crops and economic return to the farmer will be the main governing factor. Soybeans have been adapted to an increasingly broad spectrum of soil and climatic conditions. It appears they can be grown in at least the more temperate zones of practically all the tropical and subtropical countries. Apparently, however, the precise limits of high temperatures and high rainfall have not been determined as yet.

Yields in the United States undoubtedly can be increased through research. For example, better methods of chemical weed control might be developed. There is an opportunity for a relatively rapid increase in yields in Far East Asia through introduction of new varieties presently available, combined with appropriate attention to other aspects of crop management. This approach provided a doubling of yields in southern Taiwan. Such yield increases can be of great importance in countries, particularly in Asia and the Far East, that already depend on soybeans for a considerable part of the protein in their diets through traditional preparations. Incidentally, a lower cost raw material would be available for new products such as full-fat soy flour.

More attention may be given to protein quality and quantity in soy breeding in the future and also perhaps to the elimination of heat labile factors such as trypsin inhibitor, provided a sufficient advantage in processing can be foreseen.

The Role of Soy Foods

The role of soy foods in developing countries will be played within the drama involving new approaches in general agricultural development and food technology. There will be a number of important leading and supporting roles played by such developments as greater efficiency of animal production,

introduction of new cereal varieties improved with respect to protein quality and quantity, synthetic amino acids, concentrates from oilseeds other than soybeans, microbial proteins, and we could list many others.

The economic aspects of food oil supply and demand will also affect the role of soybeans; this will also be a factor in the use of defatted or low-fat soybean protein concentrates for poultry and swine production, as well as in edible products.

Higher and more efficient production of grain legumes other than soybeans can make an important contribution, but soybeans offer special advantages with respect to yields under favorable conditions and nutritive value of the protein. It has been difficult to increase production of grain legumes other than soybeans through greater economic incentive to the farmer based on the consumer's willingness to pay a higher premium for these beans and peas as compared with cereal grains. Soy flours or concentrates probably will offer special advantages as ingredients of weaning food mixtures in at least some countries.

Animal protein foods will tend to be limited in supply, expensive, and generally will tend to go to the population groups least in need.

Dr. Andre, FAO, discussed the problems that can be expected in the introduction of new foods and some basic principles to be followed in attempting to introduce new foods. The need for marketing research was stressed, and this subject was covered in more detail later in the Conference.

All three regional speakers concluded that there probably will be an important role to be played by soybeans in improving nutrition in their areas. We thus have a renewed challenge to those in many disciplines who can help give soybeans a chance to play that role.

SUMMARY OF SESSION II ON NUTRITIONAL AND CHEMICAL STUDIES

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Dr. Hand indicated to us that there are several ways that you can make a soy beverage. The flavor of the beverage is certainly important, and the flavor needs to be different depending on who is going to drink it. You might like one flavor but I would like another. He brought up one problem that we are going to have a little to say about later. That is the problem of oxidation of the product before you can kill the enzymes.

Soybean protein, the isolated protein, is not as good nutritionally as the whole protein as found in soy flour. This is one thing that Dr. Leverton brought out. Thus it is an advantage to mix soybean protein foods with other foods, particularly, because soybean is low in the sulfur amino acids.

Now there are lots of things that are right about soybeans, but there are some things that need to be watched when you use them. Dr. Carlson talked about the need for adding iodine to soybean rations. This is something that has been known for many years, but people who look into the literature and find that soybeans can cause goiters forget that you might be able to counteract this by the simple addition of iodine. Phytic acid is a metal attracting agent. Such agents do have an effect on the assimilation of minerals. When you use soybean products, it is necessary to be sure that you have enough of the minor trace minerals in the diet. Another problem with soybeans is flatus. We think that through the cooperation between J. J. Rackis of the Northern Division and F. R. Steggerda at the University of Illinois, we have found an explanation of the part played by soybeans. There are, of course, some products on the market made from soybeans that do not cause flatus; and certainly it is a minimal problem when soybeans are used in a mixed diet. We believe it would be to the advantage of the soybean industry as well as to the advantage of the people of the world to know how to counteract this flatus problem, either by removing the material by economical methods or by finding how to counteract it without removing any of the nutritional materials that are present.

Dr. Rackis also dealt on another problem which has only partly been solved for the soybean, that is the problem of the flavor. When we know more about what causes the flavor in soybeans, we believe that there will be better solutions to making it bland or more flavorful.

Dr. Wolf reviewed the information on the so-called trypsin inhibitors, hemagglutinins, saponins, and isoflavones. One thing he mentioned, which I think we ought to remember, is the estrogenic activity. Now this is low in soybeans, but it is something that has not been thoroughly explored, particularly with respect to humans.

As a final note in my comments on Session II, research leads the way to improved soybean foods for people of all nations. This is one of our key sentences in the dedication. The research must not be limited to composition and properties. It is also vitally concerned in production of soybeans, production of products, and in marketing.

We have with us a Japanese visitor, Dr. Kawamura, who has been studying the carbohydrate fraction of soybeans under a PL 480 project. I have asked him to spend about 5 minutes of our time here to review his work. We think this is important because of its relation to the flatus problem.

REVIEW OF PL 480 WORK ON SOYBEAN CARBOHYDRATES

Sin'itiro Kawamura
Faculty of Agriculture, Kagawa University
Mikityo Kagawa-ken, Japan

It is a pleasure for me to have this special opportunity of presenting a brief summary of my studies on soybean carbohydrates, partly made under a PL 480 grant from the United States Department of Agriculture. Table 1 is based on an average of six United States and three Japanese varieties of soybeans. You will see that we have itemized the composition by dividing the soybeans into cotyledons (90 percent), hull (7 percent), and hypocotyl (2 percent). The carbohydrate as obtained by difference is the second largest component of soybeans, comprising 34 percent on the dry basis; it is not a minor fraction.

Table 1.--Composition of soybeans on dry basis

Item	Yield, percent	Protein, percent	Fat, percent	Ash, percent	Carbohydrate,[1] percent
Cotyledon	90.3	42.8	22.8	5.0	29.4
Hull	7.3	8.8	1.0	4.3	85.9
Hypocotyl	2.4	40.8	11.4	4.4	43.4
Whole soybean	100.0	40.3	21.0	4.9	33.9
Whole soybean FAO (1954)	--	41.3	19.6	5.1	34.0

[1] Calculated by 100-(protein + fat + ash); consists of crude fiber + N-free extract.

Table 2 shows that there are low molecular weight carbohydrates which are determined by paper chromatography on extraction with hot 80 percent ethyl alcohol followed by washing with cold water. The major three oligosaccharides are sucrose, raffinose, and stachyose, and were identified through melting points and specific rotation of free sugars and peracetylated derivatives.

On the left in Fig. 1 are my results published about 20 years ago. The defatted soybean, extracted with dilute alkali, gives 78 percent extract and 22 percent residue. By this and other analyses the rough estimation of various carbohydrates may be shown in the figure at the right.

Table 2.--Sugar composition of soybeans[1] on dry basis

	Percent	Arabinose, percent	Glucose, percent	Sucrose, percent	Raffinose, percent	Stachyose, percent	Verbascose, percent
Defatted cotyledon	69.7	--	--	6.6	1.4	5.3	+
Hull	7.3	0.02	0.05	0.60	0.13	0.41	+
Defatted hypocotyl	2.1	--	--	7.0	1.9	7.7	+
Whole soybean	100	0.0015	0.006	5.0	1.1	3.8	+

[1] The soybean contains arabinose (?), glucose, sucrose, raffinose, stachyose, and verbascose as free sugars.

Table 3.--The hemicelluloses of soybeans

	Yield percent	Methyl-pentoses		Pentoses			Hexoses			Uronate
		Rha.	Fuc.	Rib.	Xyl.	Ara.	Man.	Glc.	Gal.	GalA
Dehulled soybeans										
Hot water	2.2	t	t	--	t	++	++	t	+++	+
5 percent NaOH	6.0	+++	+++	--	+++	+++	+	++	+++	+++
Soybean hulls										
Am. oxalate	5.4	+	t	--	t	++	+	--	++	++
Soybean hypocotyl										
Hot water	20	--	--	++	--	++	t	+	++	+

Extraction sequence: hot water, 0.5 percent ammonium oxalate, 0.2 percent NaOH, 5 percent NaOH, and 15 percent NaOH.

Figure 2 shows the structure of the oligosaccharides of soybeans. Please note that, if the end fructose residue is split off, there will be formed such reducing sugars as melibiose and manninotriose.

The hemicelluloses (Table 3) are the most complicated components. If we wish to have homogeneous preparations, their yields are very low. This table shows some examples of sugar composition of separated hemicellulose fractions. Out of the hot-water soluble fraction from dehulled soybeans, we could separate pure araban and arabogalactan by paper electrophoresis. The occurrence of fucose, usually known chiefly as a constituent of seaweed polysaccharides, was discovered by us in 1961. Soybean hulls contain much cellulose and also a pectin-like polysaccharide. Recently we have found that soybean hypocotyl contains hemicelluloses consisting partly of ribose.

Figure 3 shows the parallel decreases of sugars, whiteness, and available lysine upon autoclaving at 100° and 120° C. This may prove nonenzymatic browning or amino-carbonyl reaction taking place.

Table 4 shows the changes of sugars on treating with buffer solution at pH 4.3, at 30° for 2 hours and at 40° for 10 hours. These changes are not enzymatic since also the autoclaved sample showed similar or more pronounced changes.

In summary, Table 5 shows my speculation on the nutritional significance of soybean carbohydrates. By hydrolysis with digestive enzymes, fructose may come out and be absorbed. I am now studying the next degradation by intestinal bacteria. These may produce organic acids from sugars. The bottom figures show caloric values of raffinose and stachyose per gram, if only fructose residues are utilized. Earlier in the Conference, the soybean oligosaccharides were accused by Steggerda and Rackis of producing gas. These oligosaccharides may be valueless or undesirable, if taken too much at a time. We Japanese eat soybean foods, miso, soy sauce, and tofu, every day or almost every day but not so much at one meal. I wish to evaluate stachyose and raffinose nutritionally. Even some part of hemicelluloses may be calorogenic, I suppose. The value of 1.68 calories per gram of total carbohydrate in soybeans used in the Food Composition Tables for International Use (FAO) might be revised after studies now undertaken in our laboratory at Kagawa University are completed.

I would like to make one further comment. Dr. Hand mentioned that if you soak soybeans, particularly cracked soybeans, in water for about 5 minutes, that the material was rancid. Mr. Mustakas, who spoke earlier in the Conference, has some experiences along a similar line that he would like to describe to you.

Table 4.--Changes of sugars on isoelectric treatment (pH 4.3)

	Raw			Autoclaved		
	Alc.	30° 2 hr.	40° 10 hr.	Alc.	30° 2 hr.	40° 10 hr.
Fructose	--	0.12	0.22	t	0.55	1.63
Glucose	0.34	0.33	0.56	0.86	0.65	0.78
Galactose	--	0.39	0.74	1.16	0.51	0.73
Melibiose	--	0.12	0.08	t	0.42	0.44
Reducing	0.34	0.96	1.60	2.04	2.13	3.58
Sucrose	2.61	3.75	3.58	2.32	3.40	1.45
Raffinose	0.55	0.64	0.26	0.92	0.73	0.32
Stachyose	5.04	2.01	0.89	2.32	1.93	1.08
Verbascose	t	t	t	t	t	t
Nonreducing	8.23	6.42	4.76	5.56	6.10	2.87
Total	8.57	7.38	6.36	7.60	8.23	6.45

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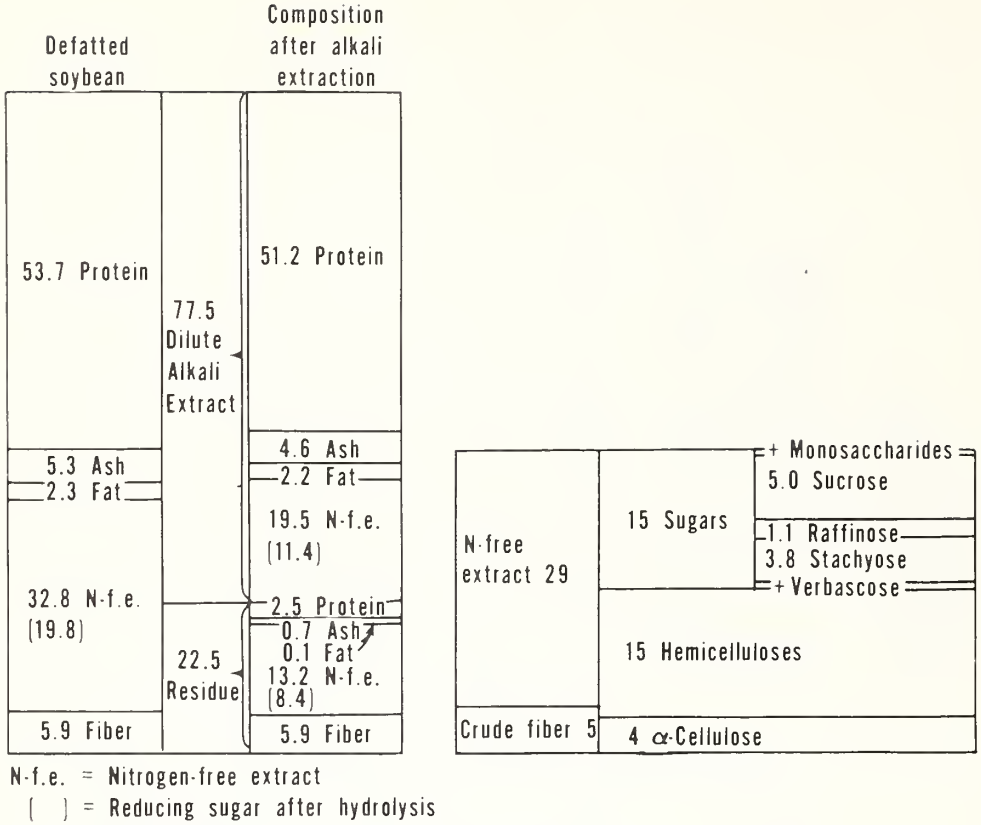
Table 5.--Nutritional significance of soybean carbohydrates

	Hydrolysis by digestive enzymes	Degradation by intestinal bacteria
Sucrose	Fructose + glucose	
Raffinose	Fructose + melibiose	Glc. + gal. → Org. acids
Stachyose	Fructose + manninotriose	Glc. + 2 gal. → Org. acids
Verbascose	Fructose + Verbascotetraose	Glc. + 3 gal. → Org. acids
Hemicelluloses	- - - - - - - - - -	Rha., fuc., rib., xyl., ara., man., glc., gal., galA → acids
Cellulose	- - - - - - - - - -	- - - - -

Sucrose 3.74, raffinose 1.35, stachyose 0.94, total carbohydrate 1.68 (FAO).



N-f.e. = Nitrogen-free extract
( ) = Reducing sugar after hydrolysis

Figure 1. Rough estimation of various carbohydrates

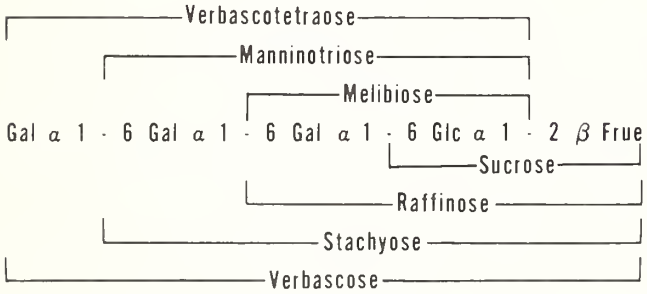
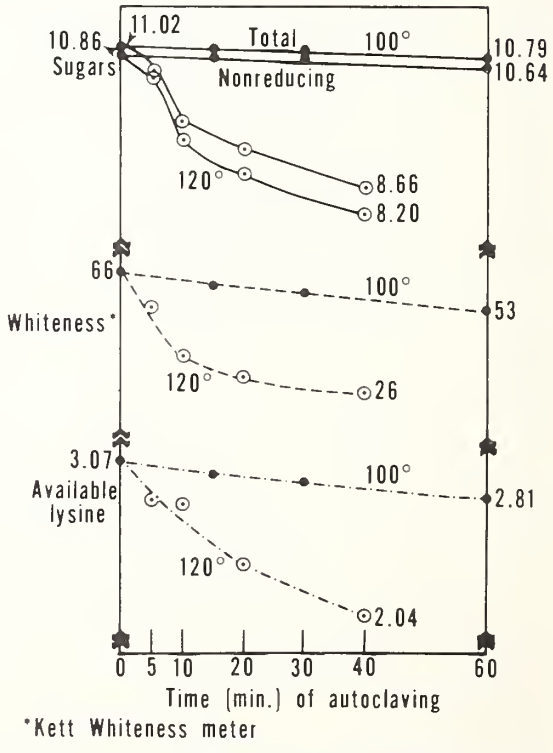


Figure 2. The oligosaccharides of soybeans



*Kett Whiteness meter

Figure 3. Decreases of sugars, whiteness, and available lysine on autoclaving defatted soybean flakes

COMMENTS ON EFFECT OF SOAKING SOYBEANS

Gus C. Mustakas
Northern Utilization Research and Development Division
Agricultural Research Service, USDA
Peoria, Illinois

I would like to comment on recent work in connection with our village process soy flour. In our soaking operations, we carried out bacteriological studies which I did not report earlier. In addition, we studied the lipoxidase activity of the soybeans during the initial soaking, and also the lipoxidase activity of the whole soybean used in our process versus cracking the beans and then soaking them. We found dramatic differences, particularly in the very early period of the soaking. When we soaked up to 4 or 6 hours, there was quite a difference in the lipoxidase activity, and high peroxide values were obtained. This difference was not as great after a longer period of time, say 30 to 40 hours. In other phases of our work, we think that enzyme action is contributing to poor stability and poor flavor. We feel that oxidation is induced by improper conditions of processing. This can develop fishy odors in the flour. I believe this is all I can say at this time since our studies are incomplete.

SUMMATION OF PANEL DISCUSSIONS ON NEEDS, POTENTIALS, AND ROLE OF SOY

Leonard L. McKinney
Northern Utilization Research and Development Division
Agricultural Research Service, USDA
Peoria, Illinois

I would like to conclude this panel discussion with a few comments. I have been very much interested in the carbohydrate work just discussed by Dr. Kawamura, having gotten it started several years ago; it is now beginning to come to fruition. Dr. Kawamura's work plus that we had done in Dr. Hirst's laboratory at the University of Edinburgh have shed considerable light on soybean carbohydrates. We are indebted to Dr. Anson for getting Drs. Aspinall and Hirst interested in doing the work on soybean polysaccharides.

After Dr. Teply's remarks, I think we would all agree that there are nutritional deficiencies among various populations over the world. Dr. Cowan's remarks point out that we know a great deal about soybeans and their nutritional properties. If we did not know much about them, we could not have had this Conference. That is the reason we are aware of the problems of utilization. Soybeans differ from other beans primarily because of the fact they contain no starch; therefore, they are hard to cook. They do not swell on cooking, because they do not contain any starch to gelatinize. Thus they are not readily converted to an edible form on cooking, and other means must be sought to make them edible. Soybeans contain oil as a source of calories instead of starch.

There is nothing unique about the trypsin inhibitors in soybeans. These are found in almost all seeds, including peanuts and cereals as well as other beans. In fact, some of the cereals have been reported to have heat stable trypsin inhibitors. There is nothing unique about soybeans containing hemagglutinins. These are also found in other beans, such as kidney beans and black beans which are used as staple foods. There is nothing unique about having to cook soybeans before you eat them. We cook most foods before we eat them. Because man fears the unknown more than he does the known, we shall continue to learn more about soybeans for the purpose of alleviating these fears. Now, are there any questions regarding this part of the program before we proceed to our next panel discussion?

Dr. J. J. Rackis: There seems to be some very strong evidence that raffinose and stachyose are not digested by mammalian enzymes and therefore there is no fructose split off. I have not seen Dr. Kawamura's data so I would like to know whether he has data to show that the mammalian digestive enzymes are able to knock the fructose moiety off of raffinose and stachyose.

Dr. Kawamura: I have not yet proved that invertase can split off fructose. I am now studying it. We have found intestinal bacteria with alpha-galactose activity on these sugars.

Dr. R. J. Dimler: As an old carbohydrate chemist, I would be very suspect about what the hydrochloric acid in my stomach is doing to that fructose linkage in the sucrose moiety. When I am taking antiacid tablets, they might get by; otherwise, I am very sure that one is likely to have that fructose split off simply by the acidity of the stomach.

Mr. L. L. McKinney: We are fortunate to have gotten another grant with Dr. Kawamura in which he is going to study enzyme activity on raffinose and stachyose, so we probably will be hearing more from him on this in the next 2 or 3 years.

INTRODUCTION TO PANEL DISCUSSION ON SOY PRODUCTS AND MARKETING

Glenn H. Pogeler
President, Soybean Council of America
Arlington, Virginia

As an introduction to the panel discussion on soy products and marketing, I would like to offer a few comments on the Soybean Council of America. The business of the Soybean Council of America is to promote markets for soybeans and their products overseas. I don't believe I will put in much more of a commercial than that. I want to add that we are not in the business of promoting the growing of soybeans overseas. Some people who come to us and want us to help develop programs for production overseas will have to understand that that is not our mission. The Soybean Council is not paid to do that. We can tell them where they can get information. If they want information on growing soybeans, literature is available in large quantities.

We are learning something every day about market development work and about the potential for soybeans and soybean products overseas. We work closely with the Foreign Agricultural Service, Fats and Oils Division, U. S. Department of Agriculture. Mr. Hugh Robinson told you that we contract with them to use soft currencies for market development programs overseas. We have programs which are tailor-made to specific countries. Things are different everywhere. I am sure you all know this already, so I won't say anything more about it.

The program this morning and specifically the part that we are talking about now is a panel discussion on soy products and marketing. You have heard the industry men here make their presentations, giving you information on soy products as they have developed them. There is interest in the simulated meat products about which there seems to be a tremendous amount of excitement everywhere you go. During my trips overseas, one of the first things they want to talk about is soybean products for human consumption, and especially the protein products. I usually begin by talking about isolated protein. I then work my way down to concentrated protein and then to soy flour. We are going to hear a lot more about soy flour. You don't have to give me a sales talk at all about the value of soy protein around the world. Price is presently the No. 1 factor. We possess a product which has a very interesting price tag and that helps open the door immediately. We hear much about other competing protein products, whether it be fish flour or the new petroleum products. The fact is that we haven't seen the arithmetic on them. The economics of these products have not yet been figured out. I have a good idea that from a production standpoint the American farmers are in a wonderful position to be competitive. The farmer is geared up, and he knows how to produce. We have the greatest agricultural system in the world with the know-how to produce soybeans in competition with the rest of the world.

We do have our problems overseas. I recently was told by a man in Italy that Red China offers him soybeans at $5 a ton under the United States' price. I said, "I probably will concede that that statement is a fact. I don't want to insult anyone, but I think you will have to admit that the United States sets the market prices in the world because we are the major supplier. In a state marketing system they can sell at any price that they want as long as they can stand the pressure as far as the economics are applied in their own backyard. If they want to sell at $5 a ton cheaper than the United States, all they have to do is get our price, cut it $5, and they have the business." The fact of the matter is that we are the major supplier in the world and this is a wonderful feeling. It certainly is from the standpoint of someone who has spent a lifetime in the business of trying to sell our products, knowing that we have a product that we are able to put on the market every day. We are going to stay that way, I believe. I feel that American agriculture is dedicated to that kind of a policy.

As we try to recap what has happened here--I must admit that I have received a lot of good ideas from the remarks we have heard in regard to soy protein products. The remark this morning about white veal was interesting. We are working on that project ourselves as we are trying to put some information together to run a test using soy protein. In Europe, pressure is coming from trade interests in the United States to try to convert them to feeding their little calves to something heavier than present weights before slaughter. Maybe we can get some other parts of the world to produce and eat the kind of T-bone steaks and sirloins we in the U. S. are used to. I know you will immediately say it costs too much money. Somehow they should be able to put a little more meat on one of those calves before they send it to the slaughter house. I believe that the feed conversion machine that is on four feet could stand to carry more weight. There is much interest in the use of soy flour in calf milk replacers. You are going to hear more about it, and the Soybean Council is going to be doing work on it.

As far as the European feed demand is concerned, the statistics are available; you know about the tremendous expansion. Hugh Robinson talked about the developed markets of Northern Europe and the opportunities still there. I think he is right.

We are going to witness, I am sure, an expanding usage of soybean oil in Northern Europe. This is in spite of the fact that average consumption of fat per person is high and runs anywhere from fifty to sixty-six pounds in Northern Europe. We have our foot in the door and are going to move in with more soybean oil that will be used in the finished products in Northern Europe. We have some real tough competition there because of whale oil, peanut oil, and the other oils which come in from other exporters.

When we get into what we call the underdeveloped countries, we will continue to work with the Food for Peace Program, as represented by AID, in the formulation of new products. Industry has been cooperating and will continue to do whatever it can to the limit of the opportunities and possibilities. I want to remind you that it isn't easy to get industry to do a lot of free research on Government programs. Industry says research costs money--big money--and their stockholders are expecting them to return dividends. They have to meet the cost of operation and show a profit. When a special product is developed which is to be used in an aid program, the purchase must be made on an industrywide competitive basis. Unless the new product has immediate commercial possibilities, industry is reluctant to spend a lot of development money without seeing a possibility of getting a reasonable return in the near future. I am not trying to tell you that industry wants a big profit from each new product, but you know very well that you have to get your money back or you are not going to be in business very long. These are the problems that we have to work with.

I shall stop at this particular point because we have two men here on the program who are experts on this subject, and I'm going to turn the program over to them. Each is to make his own recap of how the program has shaped up. We are now going to ask Dr. Wilcke to take over and present his recap. Dr. Milner's recap will follow immediately.

DISCUSSION OF SESSION III ON MANUFACTURED SOY PRODUCTS

Harold L. Wilcke
Vice-President, Ralston Purina Company, St. Louis, Missouri

Fortunately the title of our panel did not indicate summary and I am not going to summarize. The discussions at this Conference have established the need for protein in many areas of the world. Increases in soybean production have been traced from a very small beginning to an annual crop of almost a billion bushels, indicating a potential source of supply of protein which might help answer this need. This potential may take various forms. It is evident by the array of processed products that have been described here yesterday and the day before. The question now becomes, "Can any or all of these products be used satisfactorily in the human diet"? It must be remembered that there were some very unsatisfactory experiences in the use of soybean meals in human diets immediately following World War II, and I had the same experience that Dale Johnson had; I talked to people there who did not want any part of soybeans.

We have been brought up to date on the status of the two most important problems in the use of soy products, flavor, and flatulence. Neither has been solved but much progress has been made. Do the methods described for the processing of the product reduce these problems to an acceptable level as we see them today? These are questions that each processor and each user of the products must answer and evaluate for himself.

If the answer is in the affirmative, the marketing problems must be evaluated. This must be done on the basis of individual geographic areas on the basis of needs, based upon effective demand rather than on total requirement. By effective demand, I mean the quantity that can be sold. This quantity may not provide entirely adequate diets. The purchasing power of the area may dictate that improvement in diet short of complete adequacy may be necessary as a first step. We must accept whatever improvement in nutritional status that is possible where perfection cannot be achieved. I think too many times we have backed off because we could not solve the total problem. It is entirely possible that the more sophisticated products may meet a need for food for the more affluent segment of the population. This type of product may well carry some of the cost of distribution of the lower priced items in these developing countries. It is not enough to produce products; there must be channels for distribution to the point of need. In the beginning, it is entirely possible that only urban points of distribution may be feasible, or at least central points, with the hope that these may be accessible to the rural population.

All of this means that if this is not to be just a sterile group of discussions, it is going to be up to everyone of us to assess the opportunities that have been presented and to institute proper action. Now as a specific, is it not time that this industry formulate standards of identity for the products we have been talking about, including sanitary standards? It was mentioned yesterday that when contracts were let, we weren't talking about the same kind of product, even though it had the same name. Isn't it time that we insure, for our own self-protection, that the products we are talking about will meet a known set of standards? Mr. Robinson said this morning, "Know your product, know your customers, and make sure your customers know your product." Are we doing this today? Shouldn't this be one of the results of a Conference of this kind? It is not enough to talk about these things; I think we need some program to tie this thing up and to get some definite recommendations out of a meeting of this type.

DISCUSSION OF SESSION IV ON MANUFACTURING AND USE OF SOYBEAN PROTEIN PRODUCTS IN VARIOUS COUNTRIES

Max Milner
Chief, Nutrition Branch, Health Service
Agency for International Development, Department of State
Washington, D.C.

Like Dr. Wilcke, I do not intend to make any specific summary. I would, however, like to review a few topics touched on first in the comments of Dr. Mehren and my colleague Frank Ellis. I think some of these ideas need more detailed exploration at a meeting like this.

What I wish to emphasize is the self-help philosophy which now dominates the thinking of the Congress and the policy-making levels in Washington, D.C., in relation to our future efforts in dealing with the world food problem as it is today. In this regard I think Mr. Ellis made the point, as did Dr. Mehren, that we are in an entirely new ball park; in fact, we are in an entirely new ball game. The years of surpluses and the surplus-disposal philosophy are gone. Recipient countries must show genuine efforts of their own to solve their food problems. I would emphasize also another point made by Dr. Mehren--that from now on we are going to export fewer commodities and far more technology and technological know-how. I find that there exists considerable ignorance on the part of the American public of the extent to which the past U.S. policies have inhibited export of food production technology to countries which need such help if they are to feed themselves. To put it bluntly, Congress in the past, and even until very recently, has not been inclined to help countries produce those foods which have been in surplus in the United States. I think we can all agree now that this has been a shortsighted policy, because catastrophic world food shortage is virtually upon us, and it takes time to change such thinking. Our marching orders are now clear for the first time. They appear in the Foreign Assistance Act of 1966 which has just cleared Congress, in the form of what is called the Mondale Amendment introduced by the Senator from Minnesota. This amendment provides that "in developing countries where food production is not meeting the demands of population or diets are seriously deficient, high priority shall be given to increasing agricultural production, particularly through adaptive agricultural research programs based on cooperative undertakings between universities and research institutions in the United States and in the developing countries." This statement indicates the dawn of a new day in terms of what we must now do.

This document I am quoting happens to be a draft of an elaboration of these ideas being discussed in the Agency, which goes on to say, "Past efforts by the United States in agriculture designed primarily to transfer U.S. know-how have stressed the importance of the extension mechanism without

sufficient consideration of the fact that most plant varieties from the temperate zone of the Western Hemisphere are not readily transferrable to the tropical or subtropical environments of Latin America, Africa, and the Near and Far East. Similarly (and I think this statement comes very close to the subject of this Conference) U.S. practices and equipment are not necessarily well suited to the physical and economic conditions of small farm agriculture or food processing." One can point to the fact that in Latin America, after 15 years of multimillion dollar AID effort, there exist countries which are producing 30 percent less food per person than when the AID program started. I think this is the dimension of the challenge which faces us, and I think it indicates what must be done in the future.

Turning now to soybean food technology efforts and what we are going to do to meet the challenge proposed at the beginning of this meeting, my personal conviction is that we have been moving along two rather different paths in soybean technology which are not adequate to meet all needs. We have the admirable, sophisticated approach that General Mills and some of the other companies are taking, whose products we sampled the other night. Such products are definitely one important aspect of the future in soybean technology. On the other hand, I think that we have been promoting some products which are too primitive to be acceptable as human foods. As a U.S. food technologist, I have the feeling that some of the commercial companies involved have not assigned their first team to the job. There have been a number of efforts using simple soy products, other than INCAPARINA, which as some of you know have not done very well. I believe that this is because companies have not assigned their best food development and marketing people to these efforts. We are going to have to do a lot better than we have done, and I think that Dale Johnson's remarks are very much to the point in that regard. A spectrum of products must be developed to fill more adequately the gap between those of the General Mills type and the simple defatted soy grits and flours.

In terms of the new philosophy of exporting U.S. technical know-how, I feel we must become our brother's keeper. I think U.S. industry has a great deal to offer to developing countries in basic techniques for food development, processing, and marketing. I would agree with Mr. Pogeler that to a large extent industry must abide by the dictates of the shareholders in terms of the profit motive. But I think that the dialogue must be intensified between these companies and our Government in order to open doors to their efforts abroad. We believe that AID is responding in a much more sensitive and effective way than previously to the needs of U.S. firms wishing to begin operations in developing countries. But I would like to emphasize that the effectiveness of this program to export U.S. know-how through private enterprise can come about only to the extent that U.S. industry abrades (and I use the term advisedly) on AID and on the U.S. Government. Industry has much to offer, but I would hope that they would include in their proposals the use of their first team rather than haphazard and inadequate approaches which will not get the job done.

There is one example I would like to mention. There has been much promotion effort abroad of a simple soy beverage product made from defatted flours with some added gums as stabilizers, and flavoring. The promotion that has been done so far raises many problems about the product. Yet we know that if instead of defatted flour we substitute full-fat soy flour, we achieve a much higher level of acceptance. I therefore pose the question: Why not base beverage products on full-fat soy flour whose nutritional effectiveness and acceptability was so dramatically demonstrated here by Dr. Huang and others? I am convinced that there are simple but effective approaches which can be taken, which we have not capitalized on.

Finally, I have the impression that many of the presentations at this meeting, particularly from the scientific and technical point of view, seem to assume that everyone here is either a biochemist or a chemical engineer who has spent a lifetime in soybean technology. Some of you not intimately acquainted with soybeans as food, after listening to several of these papers on the flatus factor and on the variety of toxic and antibiological factors in soybean, would begin to worry whether we are not perpetrating on consumers something rather undesirable in terms of promoting soybean foods. To improve your perspective I refer you to Dr. Graham's paper and to Dr. Huang's paper which emphasize that certain low-cost soy products are available which do fill a definite nutritional need and which are entirely acceptable. These positive factors must be considered in retaining proper perspective. Thus, there are soy products eminently suitable for making a major dent on the world's protein problem. The tremendous potential of soybeans in affecting the world protein problem can be illustrated by the fact that if you were to convert all of the present U.S. soybean crop to full-fat soy flour alone (and I believe this calculation is an underestimation), you could feed 800 million children in the world with 40 grams of protein a day and do it every day of the year. Obviously this is not a practical suggestion, but it does indicate the dimension of this tremendous food resource.

SUMMARY OF CONFERENCE

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My final contribution, I am sure, should not be a "Summary" of the Conference, rather a "Benediction." We have already had the Conference well summarized.

Now we have reached the end of the program. We have covered a tremendous amount of ground; we have had a wonderful group of people here presenting their thoughts and their experiences; equally, we have had a wonderful group of people listening. We have recognized problems. We have seen research in action. We have seen answers to some questions, and we have seen other questions still waiting to be answered.

I have shared with some of our speakers the feeling that, in research, we often put too much emphasis on problems to be solved. As a result, we come out with the impression that the things under study are not very good. Yet soybeans are good. We will remember that the soybean is the "golden nugget" that holds a great deal of promise today and for the future.

We have seen the problems of marketing as a key part of the overall question of putting soybeans in their rightful place relative to the needs of the world.

We have certainly had challenges thrown at us--by Dr. Mehren and by others including, most recently, Max Milner. These are challenges that each of us, I feel, must take to heart in our own activities and in our contacts with others.

So where do we go from here? I am sure we can only go forward. I am hopeful that we go from here with a positive outlook but still at the same time a realistic outlook--both optimistic and pessimistic. I know that we go from here with a better understanding of one another's problems and with a better understanding of the opportunities that lie ahead.

This Conference has been dedicated to the problem of coordinating research to help find better solutions to the feeding of world populations. I hope and trust that when we gather again, we will have seen still further progress.

Conference on

SOYBEAN PROTEIN FOODS

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